

**A multimethod exploration of urban greenspaces and mental
well-being: Age differences, virtual simulations, and the
impact of crowding**

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Abstract

This thesis took a holistic, multimethod approach to the topic of urban greenspaces (UGS) and mental well-being and explored three aspects which were identified as gaps in a narrative literature review, (1) the importance of age (2) the presence of other people in UGS, and (3) new technology such as virtual reality (VR) as a research tool.

The first study was qualitative, and explored how properties of UGS could shape the mental well-being of multiple age groups. By conducting semi-structured interviews, similarities were found across ages: UGS are places to escape to, there are practical and accessibility needs, being spaces to share with others, and the importance of seasonal multi-sensory components.

Two pilot studies aided in methodological development of a final experimental study. These studies used virtual exposure to different urban and natural environments and measured several well-being outcomes. The first demonstrated the need for a combination of psychological and physiological measures of well-being due to divergent results. The second study supported using multiple measures of well-being and highlighted the benefits of also collecting qualitative data. The study used VR as a research tool, comparing with flat-screen exposure to restorative environments, and found increased levels of immersion with VR exposure.

Building on these experimental studies, a final study tested the impact of other people being present in UGS. Results showed that environments with no, or few, people in them were associated with greater stress reduction, greater differences in perceived restorativeness, and greater reductions in diastolic blood pressure, than an environment with lots of people in. Environments with a few or lots of people in them were associated with greater increases in energy and higher social connectedness compared to the environment with no people. The findings indicated a potential trade-off between different dimensions of well-being (restorativeness and social connectedness) in more and less crowded UGS. Effects were more pronounced in middle-to-older aged adults.

Policy and practice implications include the need to consider a range of ages in UGS design, and the research adds to methodological knowledge about measuring well-being and the use of VR as a research tool.

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List of abbreviations

ANOVA	Analysis of variance
ART	Attention restoration theory
EEG	Electroencephalography
ESRC	Economic and Social Research Council
FREC	Faculty Research Ethics Committee
FS	Flat-screen
HMD	Head-mounted display
LMM	Linear Mixed Model
MANOVA	Multivariate analysis of variance
MENE	Monitor of Engagement with the Natural Environment (survey)
NHS	National Health Service
PRS	Perceived restorativeness scale
RQ	Research question
SPSS	Statistical package for the social sciences
SRT	Stress recovery theory
STAI	State-trait anxiety inventory
SWDTP	South West Doctoral Training Partnership
TA	Thematic analysis
UGS	Urban greenspace(s)
UWE	The University of the West of England
UWIST MACL	University of Wales Institute of Technology Mood Adjective Check List
VR	Virtual reality
WHO	World Health Organization

List of research outputs incorporated into thesis

Paper 1 (Chapter 3): How properties of urban greenspaces shape well-being across age groups: A qualitative study

Reece, R., Elliott, L., Bray, I., and Bornioli, A. (2024). How properties of urban greenspaces shape well-being across age groups: A qualitative study. *Wellbeing, Space and Society*. 7, 100206.

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Paper 2 (Chapter 4): Exposure to green and historic urban environments and mental wellbeing: Results from EEG and psychometric outcome measures

Reece, R., Bornioli, A., Bray, I., and Alford, C. (2022). Exposure to green and historic urban environments and mental well-being: Results from EEG and psychometric outcome measures. *International Journal of Environmental Research and Public Health*. 19(2), 13052.

<https://doi.org/10.3390/ijerph192013052>

Paper 3 (Chapter 5): Exposure to green, blue and historic environments and mental wellbeing: A comparison between virtual reality head-mounted display and flat-screen exposure

Reece, R., Bornioli, A., Bray, I., Newbutt, N., Satenstein, D., and Alford, C. (2022). Exposure to green, blue and historic environments and mental well-being: A comparison between virtual reality head-mounted display and flat-screen exposure. *International Journal of Environmental Research and Public Health*. 19(15), e9457.

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List of relevant research outputs not incorporated into thesis, published during PhD registration (including co-authorship)

Measures of green space exposure and their association to health-related outcomes for the periods before and during 2020's Lockdown: A cross-sectional study in the West of England

Found, A.T.Z., Sinnett, D., Bray, I., McClatchey, R., and **Reece, R.** (2023). Measures of green space exposure and their associations to health-related outcomes for the periods before and during 2020's Lockdown: A cross-sectional study in the West of England. *Land*. 12(4), 728.

<https://doi.org/10.3390/land12040728>

Exploring the impacts that virtual nature exposure can have on health and well-being and the mechanisms involved: A systematic review

Reece, R., and Merchant, S. (2023). Exploring the impacts that virtual nature exposure can have on health and well-being and the mechanisms involved: A systematic review. *The Open Review*. 8, 71-86.

<http://doi.org/10.47967/TOR2022COL/VOL8.06>

Exploring the role of exposure to green and blue spaces in preventing anxiety and depression among young people aged 14-24 years living in urban settings: A systematic review and conceptual framework

Bray, I., **Reece, R.**, Sinnett, D., Martin, F., and Hayward, R. (2022). Exploring the role of exposure to green and blue spaces in preventing anxiety and depression among young people aged 14-24 years living in urban settings: A systematic review and conceptual framework. *Environmental Research*. 214(4), 114081.

<https://doi.org/10.1016/j.envres.2022.114081>

Chapter 1: Introduction

1.1. Context and rationale

The world currently faces a mental health emergency with 970 million people living with a mental disorder in 2019 (World Health Organization, 2024c). Diagnoses of anxiety and depression are particularly prevalent with 301 million people globally living with anxiety and 280 million with depression (World Health Organization, 2024c). In recent years there has been a notable change in perspective, in that research and policy have started to shift from treating mental health problems to instead taking a more preventive approach by promoting and improving mental well-being through examining how social and environmental contexts shape this.

A key social-environmental trend in recent decades is that of increasing urbanisation and the majority of populations choosing to live in urban areas (Angel et al., 2011; Department for Environment Food & Rural Affairs, 2019; Ritchie & Roser, 2018). Living in an urban area can provide numerous economic and social benefits as well as better access to health and care services (Dunn & Coulton, 2016) but has also been seen as a threat to public health (Ventriglio et al., 2021), particularly attributable to reduced capacity to access spaces for stress relief and restoration (Stigsdotter et al., 2010).

One way to combat the negative effects of urban living and to promote positive mental well-being is to include greenspaces in urban areas. An extensive literature base supports that greenspaces within urban spaces, or 'urban greenspaces' (UGS), can improve the mental well-being of residents (Callaghan et al., 2020; Hartig et al., 2003; Jabbar et al., 2021; Wood et al., 2017). Key theories and frameworks from environmental psychology underpin these beneficial effects, including Attention Restoration Theory (ART) (Kaplan & Kaplan, 1989), and Stress Reduction Theory (SRT) (Ulrich, 1981).

There is a plethora of research which has focused on the natural features of UGS and how they promote well-being, and less research has given a wider consideration to the social factors of these spaces. Firstly, research to date tends to be indiscriminate about age when exploring the properties of UGS which can benefit the visitor, rather than overtly studying the perceptions of separate age groups to understand how UGS could benefit mental well-being and social connectedness across the life course. So, the first aspect of this thesis will involve a broad exploration into greenspace properties which shape these, adopting an approach which considers multiple age groups and using a qualitative research

methodology. By doing this, this thesis also aimed to advance the qualitative research in the field.

Secondly, the field is dominated by experimental studies which attempt to isolate properties that may be particularly beneficial for outcomes related to mental well-being. However, there are limitations to these studies and gaps which need to be addressed. First, new research tools like virtual reality (VR) are increasingly popular and can be advantageously used for manipulating stimuli in experimental studies requiring control and laboratory settings. Another aim of this thesis was to look practically at whether emerging VR technology can be used as a feasible tool in such research. A second limitation relates to existing experimental studies' focus on those natural features which might best promote mental well-being, rather than other properties. Relatedly, the third and final aim of the thesis, informed by the findings which came about from investigating the first and second aims, focuses specifically on the social aspects of UGS, noting that experimental research often neglects the effect that other people being present has on the experience of being in an UGS.

1.2. Overarching aims and research questions

This thesis has three aims which inform three overarching research questions. The first aim of this thesis is to explore broadly what multi-sensory properties of UGS are beneficial for mental well-being. This thesis aims to explore which specific properties of UGS are beneficial and whether this is the same across different ages. The overarching research question which addresses this aim is:

RQ1: What multi-sensory properties of urban greenspaces are beneficial for mental well-being for different age groups, and what are the commonalities across generations?

The second aim of this thesis focuses on the exposure methods in this field and how new technology, specifically VR, can be used as a research tool for exposure. This thesis aims to explore this further to look at whether this exposure method is feasible and acceptable for research on the topic of UGS and mental well-being. The overarching research question which addresses this aim is:

RQ2: Is virtual reality (VR) a feasible and acceptable tool for researching the multi-sensory benefits of urban greenspaces for mental well-being?

The final aim of this thesis takes a narrow focus on the social aspect of UGS and how this factor can impact the experience of UGS. Additionally, this aim continues with the theme of

RQ1 by considering age as a modifying factor, as well as using VR as a research tool whereby this decision is informed through RQ2. The overarching research question which addresses this aim is:

RQ3: How does crowding in urban greenspaces impact social and perceived restorative outcomes?

1.3. Thesis structure

This is an alternative format thesis, whereby some chapters (3,4,5) are comprised of a research article which has been published during the registration period of the PhD. These chapters include the content of the research article, as well as additional writing which expands on the restricted word count of the journals where the articles were published. Chapters which are comprised of a published research article also include a commentary and contextualisation at the beginning of the chapter which states its contribution to the thesis as a whole. A section at the end of these chapters outlines what has been learnt from conducting the study and how this is taken forward into the following chapter, in order to demonstrate development and progression over the studies.

Other chapters are included as traditional thesis Chapters (2,6,7). Irrespective of format, this thesis is structured into 7 distinct chapters. Each chapter is outlined here and depicted in diagram format (see Figure 1.1). This chapter (Chapter 1) provides the broad context of the thesis including the gap for this research and presents the three overarching aims and research questions which this thesis seeks to address.

Chapter 2 presents a narrative literature review relevant to the thesis as a whole. The literature review begins by explaining the impacts of urbanisation on mental well-being and the benefits which UGS can provide. Theoretical underpinnings are then discussed before highlighting that benefits gained from UGS are complex and can be impacted by many factors, such as age. Considering age, the review then explores evidence for UGS and health across the lifecourse. Finally, I consider methodological approaches to exposure to greenspace in experimental studies, focusing on VR as a contemporary research tool.

Following the literature review, Chapter 3 sets out the first empirical study of the thesis. This study focuses on gaining an in-depth understanding of what properties of UGS contribute to mental well-being, across a range of age groups. Several themes are identified

with there being scope to take one topic forward to inform the focus of a large experimental study (Chapter 6). Chapter 3 addresses overarching research question 1 and is included in the thesis as a published paper.

Chapters 4 and 5 set out two more empirical studies which were carried out as pilot studies prior to a final experimental study (Chapter 6). Both pilot studies are included in this thesis as published papers. Pilot study 1 (Chapter 4) provides support for some of the measures adopted in the final study (Chapter 6). This study is a first step in using virtual exposure to environments and also highlights the need to use a combination of subjective and objective measures when conducting experiments focused on environments and mental well-being. Likewise, pilot study 2 (Chapter 5) provides support for the exposure method and outcome measures used in the final experimental study. More specifically, the study provides support for VR being a feasible exposure method in this field (research question 2), in addition to highlighting the importance of triangulating outcome measures (subjective, objective, and qualitative).

Chapter 6 presents a final empirical, experimental study based on the learning from each of the previous studies (Chapters 3,4,5). The study tests out concepts arising from the qualitative study (Chapter 3) and experimentally investigates the role of other people being present in an UGS and how this can impact feeling invigorated (energised and socially connected) in an UGS, and restoration from stress. This focus comes from the theme of 'sharing a space with others' and discussion around crowding and being in a space where you can escape from people, which was identified in the qualitative study (Chapter 3). The topic of these social aspects of UGS was explored further whilst simultaneously using VR as a research tool and adopted exposure method. The methods used in this study are informed by the previous two pilot studies (Chapters 4 and 5).

It is also highlighted here the focus on different environments throughout the empirical chapters. Chapter 3 focuses on all types of urban greenspaces and begins broadly to explore this type of environment. Chapter 4 then goes on to focus on natural environments which have non-natural elements, such as historic and modern features. Chapter 5 takes the research further by focusing on restoration and environments which can be restorative (green, blue, historic). The study presented in Chapter 6 brings all of the previous Chapters together by focusing on urban greenspaces which have a non-natural element (people) and measuring how restorative they are perceived to be.

Finally, Chapter 7 summarises the main findings from the empirical Chapters (3-6), discusses how they extend research, theory, and methods in the field, presents policy and practice implications of the findings, and reflects on overall limitations of the thesis and potential avenues for further research.

Appendices are presented at the end of the thesis which include ethical approvals and documents for each empirical study presented in this thesis, additional methodological details which were not included in the journal article publications, figures and diagrams relevant to the research findings (e.g., thematic maps and codebook, mind map, framework matrix, SPSS output), and all questionnaires and interview questions.

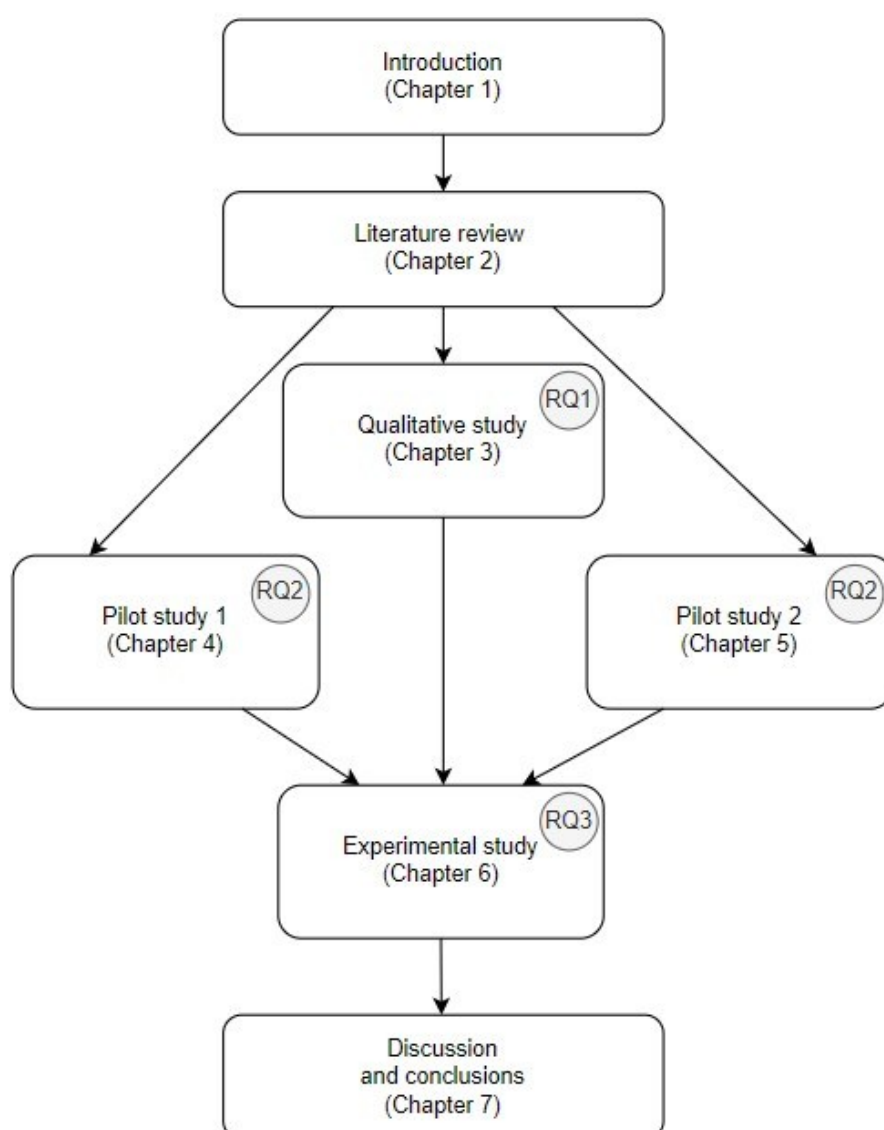


Figure 1.1. Thesis structure and the research questions (RQs) which are addressed in each empirical study.

Table 1.1 is included to provide a clear overview of each of the empirical studies included in this thesis. It also shows which overarching thesis research question is addressed by which empirical study, as well as outlining the separate research questions for each individual study. The table also clearly states which methodology has been adopted for each study, and this includes a mix of qualitative and quantitative methods.

Thesis research question		Chapter addressed in	Research paradigm	Title of chapter	Study research questions
RQ1	What multi-sensory properties of urban greenspaces are beneficial for mental well-being for different age groups, and what are the commonalities across generations?	3	Qualitative	How properties of urban greenspaces shape well-being across age groups: A qualitative study	<u>RQ1</u> : What common properties of UGS shape mental well-being similarly across age groups? <u>RQ2</u> : How do UGS support social interactions across different age groups?
RQ2	Is virtual reality (VR) a feasible and acceptable research tool for researching how multi-sensory urban greenspaces effect mental well-being?	4	Quantitative	Exposure to green and historic urban environments and mental well-being: Results from EEG and psychometric outcome measures	<u>RQ1</u> : Does exposure to urban environments with green and historic elements, and their combination, benefit mental well-being? <u>RQ2</u> : Do psychometric and physiological measurements agree when assessing the mental well-being benefits of exposure to different urban environments?
		5	Quantitative and qualitative	Exposure to green, blue and historic environments and mental well-being: A comparison between virtual reality head-mounted display and flat-screen exposure	<u>RQ1</u> : Is virtual exposure to green, blue, and historic environments associated with reduced self-reported anxiety and stress, and with physiological measures of relaxation, compared with virtual exposure to a traffic environment? <u>RQ2</u> : Are there differences in effectiveness between VR and FS exposure to green, blue, and historic environments?
RQ3	How does crowding in urban greenspace impact social and perceived restorative outcomes?	6	Quantitative and qualitative	The presence of people and crowding in urban greenspaces: examining the impacts on social connectedness and perceived restorativeness	<u>RQ1</u> : What effect does crowdedness in an urban greenspace have on psychophysiological indicators of mental well-being? <u>RQ2</u> : To what extent does crowdedness impact the perceived restorative experience of urban greenspace exposure? <u>RQ3</u> : What effect does crowdedness have on feelings of social connectedness in an urban greenspace? <u>RQ4</u> : Are RQ1, RQ2 and RQ3 impacted by age?

Table 1.1. Overarching research questions and their association with thesis chapters, research paradigms, and specific research questions posed in each study.

1.4. Multimethod and positioning

This thesis adopts the multimethod approach whereby multiple quantitative and qualitative approaches are used across the studies included. Multimethod research can be defined as, “the practice of employing two or more different methods or styles of research within the same study or research program rather than confining the research to the use of a single method” (Brewer & Hunter, 1989; Hunter et al., 2015).

Multimethod is concerned with using the most suitable method but without necessarily combining or integrating the methods and interpretation (Ivankova & Plano Clark, 2018).

It is important to clarify this here because the term is often used interchangeably with ‘mixed methods’ (Stange et al., 2006). To differentiate multimethod from mixed methods, the definition adopted here is, “Multimethod research is when different approaches or methods are used in parallel or sequence but are not integrated until inferences are being made” (Johnson et al., 2007).

To outline how multiple methods are being used here, this thesis includes a solely qualitative study using semi-structured interviews (Chapter 3), a quantitative study which adopts multiple quantitative measures (subjective and objective measures of mental well-being) (Chapter 4), and two more studies which adopt both quantitative (subjective and objective measures of mental well-being) and brief qualitative interviews (Chapters 5 and 6) (Table 1.1).

A mix of concurrent and sequential methods are used in this thesis. Firstly, a sequential approach is used whereby the qualitative study presented in Chapter 3 informs an experimental study in Chapter 6 (which adopts both quantitative and qualitative measures). However, the connection between the qualitative study (Chapter 3) and the experimental study (Chapter 6) does not constitute a mixed methods approach because Chapter 6 does not aim to explain or support the results from Chapter 3. Instead, joint inferences about these studies are collectively made in Chapter 7.

One of the advantages of the multimethod approach is that it allows for the triangulation of findings which improves robustness and reliability. It also facilitates investigation into whether different measures converge or diverge. This was a focus specifically in Chapters 4 and 5 in relation to using multiple quantitative measures which included both psychological and physiological measures of mental well-being.

Following on from the explanation of multimethod, the main philosophical approach taken in this thesis is the critical realist approach. Critical realism is an approach which was developed by Roy Bhaskar in 1975 and is popular amongst social scientists. It assumes that multiple interpretations of the world are possible (Bhaskar, 2020). Critical realism supports the use of multimethod or 'plurality' or methods and suggests that methods should be determined by need, rather than explicitly choosing either qualitative or quantitative methods. A critical realism-based approach also supports flexibility, which is another reason for choosing this philosophical approach (Adesemowo, 2023). Furthermore, critical realism is suited to investigating complex social phenomena in more depth by implementing exploration and interrogation. "Critical realism offers an alternative to engage meaningfully in studies that examine perceived realities at the empirical level and the causal mechanisms that lie behind them" (Adesemowo, 2023; Peter & Park, 2018). This allows for a more holistic approach to be taken, which was a key aim of this thesis.

A key motivation for this thesis stemmed from moving from a more rural upbringing to the urban city of Bristol and noticing the effect on my mental well-being and my preferences for certain spaces. Moreover, it is recognised in this thesis that there may be bias from myself as a researcher and having grown up in and preferring natural environments compared to urban ones.

1.5. UWE doctoral descriptors

The work included in this thesis addresses each of the UWE Bristol doctoral descriptors. Explanation of how each of these have been addressed are discussed here:

1. Have conducted enquiry leading to the creation and interpretation of new knowledge through original research or other advanced scholarship, shown by satisfying scholarly review by accomplished and recognised scholars in the field.

This thesis has conducted enquiry leading to the creation and interpretation of new knowledge through original research. This is demonstrated by all empirical studies which have been conceptualised, conducted, and presented in this thesis (Chapters 3-6). Three of these chapters (3,4,5) have been published in peer-reviewed journals, whereby I am the lead author. By publishing these chapters, it supports their original contribution to the research field and their recognition by other scholars in the field. Journals published in are in the fields of public health and environmental research.

2. Can demonstrate a critical understanding of the current state of knowledge in that field of theory and/or practice.

The literature review chapter in this thesis (Chapter 2), which is structured as a narrative literature review, demonstrates a critical understanding of the current state of knowledge and provides a broad exploration of research which spans across multiple disciplines including research and theory in public health, environmental psychology, and applied psychology. Relevant studies are discussed and critically evaluated in the literature review in order to present the current state of knowledge and identify gaps for this postgraduate research. More specifically, each empirical study also begins with a literature review specific to that study. This provides a clear overview and background to the study, as well as being a required element for publication.

3. Show the ability to conceptualise, design and implement a project for the generation of new knowledge at the forefront of the discipline or field of practice, including the capacity to adjust the project design in the light of emergent issues and understandings.

This thesis includes four empirical studies, using multiple methodologies, and shows ability to conceptualise, design and implement projects for the generation of new knowledge. For paper 2 (Chapter 4) and paper 3 (Chapter 5), I took a leading role with the methodology, data collection and analysis and writing the manuscript for publication and was the corresponding author during the publication process. For paper 1 (Chapter 3), I led all stages of the research and project management. I was responsible for the conceptualisation, methodology, data collection and analysis, and writing of manuscript for publication. I was therefore also the corresponding author during the publication process.

For the final experimental study (Chapter 6) and literature review (Chapter 2) - both traditional written thesis chapters - I have taken the leading role and been responsible for all aspects of the process, with support from my supervision team. All four studies included in this thesis have been at the forefront of the research field. In addition, the designs of the included empirical studies have adapted due to emergent issues such as the risk of transmission of COVID-19 (e.g., conducting online interviews rather than face-to-face), or adjusted to reflect findings of earlier studies in the PhD, e.g., the findings from the qualitative study (Chapter 3) forming the focus of the final experimental study (Chapter 6).

4. Can demonstrate a critical understanding of the methodology of enquiry.

A critical understanding of the methodologies of enquiry have also been demonstrated in this thesis. Each empirical study included in thesis has a separate adopted methodology which is presented in each respective chapter. Both qualitative (Chapter 3,5,6) and quantitative (Chapters 4,5,6) methodologies have been used and are outlined and evaluated in each chapter. I have demonstrated the knowledge and use of both qualitative and quantitative methodologies and their use for enquiry in the field of UGS and well-being.

Additionally, this research adopts different research designs (exploratory, experimental), research methods (semi-structured interviews, lab-based VR methods, physiological monitoring, self-report questionnaires) and analysis methods (thematic analysis, framework analysis, MANOVA and linear mixed-effects models) and these are critically evaluated within the discussion of each empirical chapter as well as collectively in Chapter 7. These were all chosen as the most appropriate methodologies and research methods for investigating the posed research questions.

5. Have developed independent judgement of issues and ideas in the field of research and/or practice and are able to communicate and justify that judgement to appropriate audiences.

The work presented in this thesis demonstrates independent judgement of issues in the field of UGS and mental well-being, as well as the methods of enquiry and contemporary research tools used to explore this topic, with a particular focus on VR. The findings of this thesis have been communicated and disseminated through peer-reviewed publications as well as at local and international conferences where the research has been presented in front of world leading scholars in the field (see Chapter 7, [Appendix 32](#)).

6. Can critically reflect on their work and evaluate its strengths and weaknesses including understanding validation procedures.

Each empirical study in this thesis includes a separate discussion section which reflects on the strengths and weaknesses of that study. An overarching discussion chapter (Chapter 7) concludes the thesis which discusses and evaluates the body of research as a whole. Strengths, weaknesses, and reflections of the whole project are included in the final discussion chapter. The studies included in this thesis that have been published have already been through the peer-review process and have all received revisions from

reviewers which have allowed critical reflection and responses to limitations of the studies. An understanding of validation procedures has also been demonstrated in this thesis. For example, appropriate methodologies for the research questions are adopted, the instruments and questionnaires implemented in several studies are validated tools, and suitable statistical analyses have been conducted.

Chapter 2: Literature review

2.1. Introduction

This chapter provides a broad literature review which informs this thesis as a whole. Empirical evidence is reviewed on the impact that urban greenspaces (UGS) can have on mental well-being, whilst also considering factors relevant to the specific research questions, such as age, the use of virtual technology, as well as aspects within UGS such as people and crowding. Literature is evaluated from across multiple research fields, including environmental and applied psychology, and public health. Key theories situated within the field of environmental psychology will also be illustrated in this chapter: which help understand the specific restorative effects that UGS have on well-being Attention Restoration Theory (ART) (Kaplan & Kaplan, 1989) and Stress Recovery Theory (SRT) (Ulrich, 1981, 1983). These theories inform this thesis and are presented alongside the empirical evidence due to their underpinning of the health and well-being benefits associated with exposure to UGS.

The structure of this chapter begins with section 2.2 outlining the current mental health epidemic and definitions for mental health and mental well-being which are used in this thesis. Section 2.3 then illustrates the impacts of urbanisation on mental well-being before moving on to discuss the importance of greenspaces in combatting the negative effects of urban living and promoting mental well-being (section 2.4). In this section, the prominent theories and health-nature frameworks explaining the effects of greenspaces and nature more broadly are also outlined. Then, a narrower focus is taken looking at UGS, including definitions (section 2.5). Empirical evidence is reviewed and discussed in relation to the importance of age in modifying how UGS are experienced and benefits derived, in addition to acknowledging these spaces as multi-sensory. Particular focus is also placed on considering the opportunities which new technologies, such as virtual reality (VR), can provide as a research tool in experimental research in the field (section 2.6). Finally, section 2.7 synthesizes the emergent research gaps which this thesis aims to address and presents the overarching thesis research questions.

2.2. Mental health and well-being

The world is currently facing a mental health crisis and the need for action is urgent. In 2019, 970 million people were living with a mental disorder (World Health Organization, 2024c), and it is expected that half of the world's population will experience a mental

health disorder at some point in their life (Queensland Brain Institute, 2023). Those diagnosed with a mental disorder often have disturbances to their thinking, emotions, behaviours, and social relations. The most commonly diagnosed disorders are anxiety and depression, with 301 million people globally living with anxiety in 2019, and 280 million people living with depression (World Health Organization, 2024c). By 2030, it is projected that mental health disorders will be the leading cause of mortality and morbidity globally (World Health Organization, 2011b).

Mental health disorders are prevalent across all age groups with more than 13% of adolescents globally experiencing a mental disorder (Keeley, 2021), and 14% of adults aged 60 and over living with a mental disorder (World Health Organization, 2023d). There are also reported gender differences which demonstrate that women are more likely to be diagnosed with a mental illness than men (World Economic Forum, 2018). Additionally, anxiety and depression are more common among women, whereas conduct disorder and attention-deficit hyperactivity disorder (ADHD) are more common for men (GBD 2019 Mental Disorders Collaborators, 2022). Overall, the mental health crisis is a huge burden of disease. Mental disorders have significant economic consequences which are from direct and indirect streams. Direct costs include medical care and hospitalizations, whereas indirect costs can include loss of productivity due to absence from employment as well as loss of employment entirely and social security funds from the government (Hewlett & Moran, 2014; NHS England, 2022; Schofield et al., 2019). Globally, mental health disorders could cost £12 trillion by 2030 (Patel et al., 2018), and in just the UK alone, mental health problems already cost the economy at least £118 billion per year (McDaid et al., 2022).

Because of the extensive impact that mental disorders can have, there is a desperate need to address this issue. Previously, a large emphasis has been placed on diagnosing and treating disorders and attending to the 'illness' side of the problem (Herrman, 2001; Singh et al., 2022). More currently, there is an increased emphasis on moving away from treating poor mental health to instead promoting and improving mental well-being (World Health Organization, 2024a). Instead of viewing mental health in a negative light, mental health promotion takes a positive approach and focuses on a more holistic and positive perspective on mental health (Gautam et al., 2024; Office for Health Improvement & Disparities, 2022). The World Health Organization state that, 'there is no health without mental health', and mental health promotion interventions are essential as they in turn can lead to improved overall well-being, lower the risk of developing mental disorders, and increase socioeconomic benefits (Jané-Llopis et al., 2005; World

Health Organization, 2024d). This is actioned by the World Health Organization's Comprehensive Mental Health Action Plan 2013-2030 whereby one of the major recent objectives is to implement strategies for prevention in mental health (World Health Organization, 2021).

When investigating mental health and well-being in research, it is difficult to synthesise evidence due to the numerous, interchangeable definitions which are used (Linton et al., 2016). Terms including 'mental health', 'mental disorder', 'mental illness', 'mental condition', and 'mental well-being', are often used interchangeably without a universal definition shared across disciplines. For example, in a scoping review which mapped the research on greenspace and mental health benefits, it was difficult to compare study outcomes and synthesise evidence regarding mental health due to the numerous terms used and lack of definitions provided (Wendelboe-Nelson et al., 2019). It was not clear whether some studies may have overlapped with their outcomes but had just adopted a different terminology. To address this challenge, systematic reviews researching mental health often included both the terms 'mental health' and 'well-being' in their search terms (Collins et al., 2020; Vanaken & Danckaerts, 2018; Wendelboe-Nelson et al., 2019). However, this does not address the initial challenge of interchangeable terminology. With the aim to provide clarity, this section of the literature review will outline the definitions of related terms adopted in this thesis.

2.2.1. Mental health

Mental health is a key factor in the definition of 'health'; "a state of complete physical, mental and social well-being and not merely the absence of diseases or infirmity" (World Health Organization, 2005). The definition adopted for mental health in this thesis is also from the World Health Organization which defines the term as, "a state in which an individual realizes his or her own potential, can cope with the normal stresses of life, can work productively and fruitfully, and is able to make a contribution to her or his community" (World Health Organization, 2005). In research studies, mental health is often operationalised as the rate, or prevalence, of disorders. For example, standardized questionnaires including the Generalized Anxiety Disorder 7 (GAD-7) (Williams, 2014b) and the Patient Health Questionnaire-9 (PHQ-9) (Williams, 2014a) are regularly used to assess the severity of anxiety and depression symptoms, as measures of mental health (Heo et al., 2021; Hystad et al., 2019). The World Health Organization report that people with poor mental health and living with mental health disorders are more likely to, but not always, experience lower levels of mental well-being (World Health Organization,

2022b). This leads onto 'mental well-being' and how this related term is defined, addressed, and measured in research.

2.2.2. Well-being

The concept of well-being dates back to the ancient Greeks (Angner, 2011), with society searching for definition of 'a good life'. This is now more prominent due to the growth of positive psychology and the focus placed on individuals being fulfilled and flourishing (Lent, 2004; Seligman, 2011). Subjective well-being relates to what a person feels and thinks of their life and is more than just a measure of happiness (Diener, 2009; OECD, 2013). Subjective well-being has been defined as, "a person feeling and thinking his or her life is desirable regardless of how others see it" (Diener, 2009), which is more in line with a hedonic view of well-being. Subjective well-being can be understood through two perspectives: hedonic well-being and eudaimonic well-being (Ryan & Deci, 2001).

Hedonic well-being emphasizes the pursuit of pleasure and happiness whilst avoiding pain and are traditionally measured in more immediate contexts, whereas the eudaimonic perspective is focused on self-realisation, meaning, and feeling a sense of purpose, and measured as a 'global' state. Taking both of these perspectives into consideration, policies are moving beyond just measuring happiness and instead showing more recognition of evaluative, hedonic and eudaimonic, and experiential aspects of subjective well-being (OECD, 2013). Evaluative well-being refers to the global evaluation which people make about their life, whereas experiential well-being encompasses the positive and negative emotions which are experienced on a daily basis (Kapteyn et al., 2015; Miret et al., 2017). Despite the definitions presented here, it should be recognised that a universal and clear definition for well-being is elusive and can differ both across and within disciplines (Jarden & Roache, 2023). This inevitably makes it difficult to measure well-being as well as compare measures of well-being across research studies. Numerous measures of well-being exist with no 'correct' measure (Cooke et al., 2016; Linton et al., 2016). Additionally, several psychometric scales used to measure well-being often include measures of spiritual and functional wellbeing, which are concepts not included in definitions of well-being (Linton et al., 2016).

In order to provide clarity for this thesis, a multi-dimensional measure of the positive aspect of mental health, as well as the absence of mental disorder, is defined here as 'mental well-being'. Those with good mental well-being have an absence of mental

disorder but also demonstrate happiness and enjoyment (hedonic well-being) (Henderson & Knight, 2012), purpose, meaning and fulfilment (eudaimonic well-being) (Ryan & Deci, 2001), are able to cope with stressors, realise their potential, have healthy social relationships (social wellbeing), and flourish (Houlden et al., 2018; Roe & McCay, 2021; Seligman, 2011). For this thesis, 'mental well-being' is adopted as the primary outcome which encompasses hedonic, eudaimonic and social well-being (Gallagher et al., 2009). This is adopted over the term 'mental health', as it encompasses a broader recognition of factors including social and environmental factors (Fleuret & Atkinson, 2007).

Mental well-being can be measured in objective and subjective ways, by assessing physiological and psychological outcomes. Research often includes self-reported, subjective psychological measures of mental well-being (Yetton et al., 2019). However, bias can be present in these measures which has led to more objective measures also being used to assess mental well-being. These physiological measures include, for example, electroencephalogram (EEG), skin conductance, skin temperature, blood pressure and heart rate (Yetton et al., 2019).

Although research on mental well-being includes clinical applications, involving clinical patients and controlled studies or treatments, the focus of this thesis is on the general population due to potential for greenspace exposure to improve population-level mental well-being. There are several determinants of mental well-being which include social factors, such as employment and socioeconomic status, education, childhood experiences, and housing (Kirkbride et al., 2024; Silva et al., 2016). Another of these key determinants of poor mental well-being is environmental factors, especially individuals living in urban areas and the negative impacts that urbanisation can have (Patil, 2014; Ventriglio et al., 2021). This crucial risk factor will be discussed next.

2.3. Urbanisation and well-being

The majority of populations live in urban areas, with urbanisation continuing to grow exponentially across the world and estimated to double by 2050 (Angel et al., 2011; Department for Environment Food & Rural Affairs, 2019; Ritchie & Roser, 2018). The United Nations reported that 82% of the population in North America live in urban areas, it was 74% for Europe, 50% for Asia, and the lowest was Africa whereby 43% of the population are living in urban settings (United Nations, 2018). The majority of this urban growth is predicted to take place in developing countries (Allender et al., 2011). Urban living offers numerous opportunities for education, employment, health care, and transportation (World Health Organization, 2010). Compared to rural areas, cities can provide better

infrastructure, socioeconomic conditions, and nutrition (Adli, 2011). So, as urban living continues to increase and the majority of the world's population spend their time in urban spaces, it is vital that they are beneficial for health and well-being rather than detrimental.

But urban living is associated with significant negative impact on physical health outcomes, including an increased risk of cardiovascular disease (Recio et al., 2016; Selander et al., 2009), obesity and diabetes (Ramachandran et al., 2008; Sobngwi et al., 2004), metabolic syndrome (Weng et al., 2007), and cancers (Sharp et al., 2014; Weiderpass, 2010). Urban spaces have been described as a cause of disease, injury and mortality (Sarkar & Webster, 2017). Additionally, urban areas are associated with increased crime rates, poor housing, over-crowding, and pollution (World Health Organization, 2010), all of which are wider determinants of health (Bambra et al., 2010; Barton & Grant, 2006; Graham & White, 2016). Exposure to air pollution in urban spaces can lead to the development of respiratory problems, such as asthma and allergies (Gehring et al., 2010; Niemann et al., 2006), and noise pollution from increased urbanisation has been found to be associated with sleep disturbances, hearing impairments, and cognitive impairments (Cyril et al., 2013; Passchier-Vermeer & Passchier, 2000).

As well as physical health risks, links between urban living and negative impacts on mental health and well-being are well-documented. Urban living can lead to increased stress (Lederbogen et al., 2011), increased risk of anxiety (Peen et al., 2010), depression (Sundquist et al., 2004), psychosis (Fett et al., 2019; Gruebner et al., 2017), loneliness (Okkels et al., 2018), and overall poorer mental health (Ventriglio et al., 2021; Xu et al., 2023). Worryingly, urban living is further associated with increased risk of suicidality and self-harm, compared to rural living (Satherley et al., 2022). These risks are also more pronounced for those living in deprived urban areas, facing challenges with urban inequalities (Okkels et al., 2018; Satherley et al., 2022).

In summary, there is extensive evidence highlighting the negative impact that urban living can have on population well-being. Interestingly, more recent research has started to explore different types of urban spaces and how certain spaces can instead be beneficial for well-being (Rydin, 2012; Taylor & Hochuli, 2015). For example, exposure to urban spaces which include historic and cultural architectural styles have shown to have restorative capabilities (i.e., stress or cognitive relief) (Bornioli et al., 2018a, 2018b; Brancato et al., 2022; Fornara & Troffa, 2009; Scopelliti et al., 2019; Weber & Trojan, 2018). Literature has further shown, through aesthetic preferences and place meaning,

historical buildings are of a high quality and can be highly restorative (Galindo & Hidalgo, 2005; Hidalgo et al., 2005). For example, places such as monasteries (Ouellette et al., 2005), houses of worship (Herzog et al., 2010), and museums (Packer & Bond, 2010) can all be restorative environments. Heritage is also an important aspect of the environment which can have a positive impact on well-being. Visiting different types of heritage, such as historic towns, places of worship, industrial sites, and archaeological sites, can have an equally positive effect on mental wellbeing as doing other activities such as sports (Historic England, 2014), and are positively correlated with happiness and life satisfaction (Department for Culture Media & Sport, 2015). In addition to historically and culturally rich environments, greenspaces can also combat the detriments of urban living and be beneficial for health and mental well-being. The wealth of literature focused on this will be reviewed next.

2.4. Greenspace and well-being

This literature review will first look at the link between greenspaces and mental well-being, before then narrowing down focus to 'urban greenspaces' (UGS) more specifically. When reviewing evidence of greenspaces and their impact on mental well-being, it should be noted that there is a lack of consensus around terminology. As with 'mental well-being', there are multiple definitions for 'nature', 'natural environments', and 'greenspace', which are used interchangeably and vary across disciplines (Taylor & Hochuli, 2017).

A definition of 'nature' often adopted as a broad umbrella term is defined by Hartig et al., (2014) as, 'physical features and processes of nonhuman origin that people ordinarily can perceive, including the "living nature" of flora and fauna, together with still and running water, qualities of air and weather, and the landscapes that comprise these and show the influence of geological processes'. This definition, adopted within the field of environmental psychology, comprises of both biotic and abiotic elements and has a specific focus on nonhuman elements. This may explain the lack of studies in the field which have explored 'human' elements of nature and mental well-being, such as the impact of historical features of a natural space, or the impact of other people being present. Therefore, there may be a bias in kind of stimuli which are used in experimental studies. In other disciplines such as ecology, this definition of nature is opposed because humans are viewed as being a crucial part of nature; as much nature as trees and animals (Kurle et al., 2023).

Moreover, the definition of nature is often used interchangeably with ‘natural environments’, which has been outlined by Natural England in The People and Nature Survey for England (which follows the Monitor of Engagement with the Natural Environment (MENE) survey which ran from 2009 to 2019). Here, natural environments include greenspaces in towns and cities (e.g., parks, canals), the countryside (e.g., farmland, woodland, hills and rivers), and coastline (e.g., beaches, cliffs) (Natural England, 2020). Further, the naturalness of an environment can be difficult to decipher and is often measured through either ecological naturalness or perceived naturalness (Krapez et al., 2021). The MENE definition of natural environments includes urban parks, which may be measured differently in regard to ecological (e.g., physical measure of vegetation) and perceived naturalness. Additionally, the definition could be considered rather broad, including both open countryside and a manicured urban park. Here, a broad approach is appropriate when discussing the evidence around greenspaces and mental well-being due to the inconsistencies in terminology used. Therefore, terms synonymous with ‘greenspace’ such as ‘nature’ and ‘natural environments’ are also included in this narrative review of the literature.

For decades, theoretical and empirical evidence has found greenspaces to be positively linked to improved health and mental well-being. Empirical evidence has implemented both quantitative and qualitative methods and been conducted across multiple disciplines including environmental psychology, public health, and geography (Bratman et al., 2019; Douglas et al., 2017; Frumkin et al., 2017; Gianfredi et al., 2021; Hartig et al., 2014; Houlden et al., 2018; Hunter et al., 2019). Presented here is a brief chronology charting: seminal theories of stress recovery and attention restoration and supporting experimental evidence (2.4.1 & 2.4.2), the influence these theories had on subsequent epidemiological work on nature and health (2.4.3 & 2.4.4), broader nature-health frameworks which resulted from this (2.4.5), and evidence of the associations between nature and health amongst children/adolescents and the contribution of nature to healthier ageing (given the predominance of adult populations in this work more broadly) (2.4.6 & 2.4.7).

2.4.1. Psycho-evolutionary theory

A key area of literature focuses on the impacts of natural environments on stress, whereby a stress response can be defined as, ‘any physical or psychological stimuli that disrupt homeostasis’ (Chu et al., 2024). The physiological response to stress comprises of a complex involvement of nervous, immune, and endocrine systems, the hypothalamic-

pituitary adrenal (HPA) axis, and the sympathetic-adreno-medullar (SAM) axis (Chu et al., 2024; Mifsud & Reul, 2018).

A prominent theory which explains the impact of natural environments on psychological well-being, and part of the larger concept of restoration, is the Stress Recovery Theory (SRT), or the psycho-evolutionary theory (Ulrich, 1981, 1983; Ulrich et al., 1991). SRT posits that being in natural environments is an affective experience and can aid in recovering psychologically and physiologically from stressful situations (Ulrich, 1981, 1983; Ulrich et al., 1991). SRT focuses on evolutionary origins of restoration. People respond positively to environments in which they would feel safe, from an evolutionary point of view. Physiologically, the parasympathetic nervous system can be impacted when exposed to natural environments, which can aid in inducing a positive change in emotional state and supporting recovery from stress. Stress recovery can be measured using physiological markers such as heart rate (Vacher et al., 2019), blood pressure (Tsunetsugu et al., 2013) and cortisol levels (Vacher et al., 2019), as well as through psychological responses including positive affective states (Tyrväinen et al., 2014), improved mood (Niedermeier et al., 2017) and self-reported stress (Schmid et al., 2021).

Early studies conducted by Roger Ulrich drove the formulation and support of this theory (Ulrich, 1981; Ulrich et al., 1991). A prominent study adopted an experimental design and involved participants viewing sixty coloured slides of scenes which either featured nature with water, nature dominated by vegetation, or urban scenes without water or vegetation (Ulrich, 1981). Outcome measures included brain activity using electroencephalography (EEG) to assess alpha wave amplitude, heart rate, and psychological measures which consisted of semantic scales and the Zuckerman Inventory of Personal Reactions (ZIPERS) affect scale (Zuckerman, 1977). The results of the study showed that views of nature (water and vegetation) had more of a positive impact on psychophysiological states than the urban scenes. When compared to the urban scenes, alpha brain activity was statistically significantly higher for participants when viewing the vegetation scenes, and this was similar for the water scenes. Finally, scenes with nature (vegetation but especially water) had a more positive influence on emotional states than the urban scenes. A further study followed which involved additional physiological measures for stress recovery (Ulrich et al., 1991). In this study, participants were first presented with a stressor which required viewing a movie about accidents at work and involved graphic scenes of injury and gore. The 120 undergraduate student participants then viewed videos of either a natural or urban setting. Stress recovery was measured using several physiological measures including heart period, muscle tension, skin conductance, and

pulse transit time (correlate of systolic blood pressure). Self-reported affective state was also measured after participants viewed the stimuli. The findings supported a positive shift in emotional state and physiological activity after scenes of nature were viewed. Stress recovery was faster after nature scenes compared to urban, and physiological measures were consistent in showing greater recovery after viewing nature.

More current research has been conducted which also provides support for SRT (Corazon et al., 2019; Yao et al., 2021). A systematic review, covering eight years of research, targeted studies which focused on the psycho-physiological effects of outdoor nature and stress recovery (Corazon et al., 2019). The review included 36 studies and included measures of psychological and/or physiological measures of stress. They found that outdoor, nature-based exposure can be associated with having a positive effect on various emotional parameters relating to stress relief. However, this conclusion is based off solely psychological measures and the results from physiological measures were more heterogenous. Additionally, a meta-analysis provides support for exposure to natural environments leading to stress reduction (Yao et al., 2021). The review included 31 studies which totalled 1842 participants of which no age restriction was applied. Studies involved exposure to a real (not simulated or in a laboratory) natural environment and had a comparator condition which was exposure to a built or urban environment. The meta-analysis concluded that an increase in natural exposure was associated with reduced physiological indicators including salivary cortisol, systolic and diastolic blood pressure, heart rate variability, as well as self-reported stress, state of anxiety, and increased restorative outcomes. Whilst a supportive study of the psycho-evolutionary theory, it was limited by high levels of heterogeneity between studies as well as some stress outcomes (e.g., EEG) which were not included in the meta-analysis and could not be compared due to the small number of studies which had implemented the measure.

Whilst these reviews provide a strong amount of support for the benefits to stress recovery that natural environments can have, it should be recognised that these are based on entirely quantitative studies and there is an overall lack of qualitative evidence which explores this association. Qualitative research could provide deeper insight into why and how there is a recovery from stress.

2.4.2. Attention restoration theory

A second prominent theory is Attention Restoration Theory (ART), which explains that it is essential to take time away from cognitively demanding urban spaces and recover our

attentional capacities in natural spaces (Kaplan & Kaplan, 1989). Being in usual surroundings (e.g., everyday work or attending to busy stimuli in urban spaces) can lead to fatigue in directed attention which can result in decreased attentional performance, negative mood, and irritability (Hartig et al., 1997). The theory posits that there are four components which can make an environment restorative: 'being away', 'extent', 'soft fascination', and 'compatibility'. Firstly, individuals need to 'be away' from life stressors and distracted from a usual environment that is cognitively demanding (e.g., work, social media). Being away from a usually demanding environment can allow for fatigued directed attention to rest (Herzog et al., 2003). Secondly, 'extent' refers to being in an environment which is comfortable and allows total immersion and engagement. By engaging the mind and allowing for exploration, the mind is occupied for a sufficient amount of time for directed attention to rest. Extent can also refer to the experience of expansive places and is sometimes also referred to or sub-divided into 'coherence' and 'scope'. Thirdly, a restorative environment must be 'softly fascinating' whereby an individual's attention is held but without effort which allows for reflection (e.g., watching clouds in the sky). 'Soft' fascination here means a peaceful kind of fascination which is characterized by a moderate level of attention which is effortless and an environment which is aesthetically pleasing (Herzog et al., 2003; Kaplan, 1995). Finally, the fourth component of 'compatibility' refers to being in an environment which aligns with an individual's motivations and preferences. This complex component can vary widely depending on an individual's needs and inclinations. Natural environments which have these components allow for the recovery and replenishment of directed attention. The environment encourages the use of a more effortless type of attention. Whilst all four components can be argued to also be found in urban spaces, extensive research supports that they are more commonly perceived in natural spaces and that natural environments are more restorative than urban environments (Herzog et al., 2002; Kaplan, 1995; Menardo et al., 2021; Ulrich et al., 1991). There have been critiques of ART who have stated that; some of the concepts of the theory lack operationalisation and are vague, and research fails to sufficiently test ART's predictions (Joye & Dewitte, 2018).

To measure the components of ART, a commonly implemented scale used in empirical research is the Perceived Restorativeness Scale (PRS) (Hartig et al., 1997). The PRS is used to measure the perceived restorative potential of environments and is an estimation of the restorative potential of environments (Hartig et al., 1997; Staats, 2012). Other similar versions of the PRS have also been formulated such as the PRS short version (Berto, 2005). Whilst arguably not as extensively implemented, other self-report questionnaires

also include the Restorative Components Scale (Laumann et al., 2001), the Restorativeness State Scale (van den Berg et al., 2014), the Environmental Restoration Perception Scale (MartínezSoto et al., 2014), and the Restorativeness Outcome Scale (Korpela et al., 2008).

Similar to SRT, systematic reviews have been conducted assessing the research which has investigated attention restoration and natural environments (Ohly et al., 2016; Stevenson et al., 2018). One systematic review included thirty-one studies which provided some support for ART and found significant effects of exposure to natural environments across three psychological measures: Digit Span Forward and Backward, and Trail Making Test B (Ohly et al., 2016). Studies included were required to have conducted an experimental design and involved exposure to a natural environment compared to another non-natural environment, included any population, and included an objective measure of attentional capacity. Again, similarly to reviews conducted focusing on SRT (Yao et al., 2021), this review was limited by the heterogeneity of included sources which makes it difficult to understand different factors such as which type of natural environment is best for attentional restoration (Ohly et al., 2016). Inhibiting distraction is key to directed attention and therefore ART, however the psychological measures used in the review are stronger in measuring short-term memory, working memory and executive function.

After this review, an updated systematic review was conducted which focused on the specific cognitive domains which are central to attention restoration (Stevenson et al., 2018). This review included forty-two studies which compared natural environments with a control and included an objective measure of cognitive performance. It found that cognitive domains which improved after exposure to natural environments included working memory, cognitive flexibility, and attentional control. A key contribution of this review was the proposal of a new framework which expands the definition of directed attention into three categories: cognitive demand, direction of attentional focus, and locus of distraction. In regard to critical evaluation of this review, a shared limitation with the previous review (Ohly et al., 2016) is the lack of homogeneity across included studies and therefore difficulty with synthesizing results. Furthermore, the studies included in the review were mostly of adult populations from developed countries, which limits the external validity of the synthesis.

Perceived restorativeness and attention in natural environments has been explored using various methods and tools of exposure, including photographs and videos. Photographs have been used when exploring stress recovery and perceived restorativeness of UGS

(Carrus et al., 2013; Wang et al., 2019). Carrus et al., (2013) showed photographs of UGS varying in amounts of naturalness to 50 undergraduate students and measured outcomes including perceived restorativeness using an Italian version of the PRS. Perceived restorativeness was shown to be highest in the peri-urban greenspaces (compared with urban forest, urban park, botanical garden, urban square) and increased with the level of naturalness. Similarly, Wang et al., (2019) used photographs and manipulated four dimensions of an UGS: trees, flowers, water and small animals (birds, fish). A key finding showed that the number of trees, and the presence of flowers or water, increased restorative potential. A positive link between aesthetic preference and restorative potential was also demonstrated. Other studies have also used photographs of nature to investigate outcomes of executive attention (for example Gamble et al., 2014). It was shown that executive attention improved in young and older adults after viewing nature photographs, compared to urban environment photographs (Gamble et al., 2014). It should be noted that this study only recruited young adults (18-25 years old) and older adults (64-79 years old), rather than all adults.

As well as still photographs, videos have also been used as a method of exposure to different experimental environments. For example, videos have been used of urban environments (including green and historic features) whilst measuring hedonic tone, perceived restorativeness, environmental perceptions and affective outcomes (Bornioli et al., 2018a). Videos have also been effective in conveying virtual nature to improve stress and attention recovery in experimental settings (Snell et al., 2019), and measure physiological indicators as part of a randomized controlled trial (Wang et al., 2020).

2.4.3. Influence of SRT and ART

The foundational theories of SRT and ART have been very influential on numerous disciplines including public health, environmental psychology, and urban planning. The theories are consistently outlined in published studies and results are often situated within their context. A wealth of research studies have since been conducted which adopt a similar approach to comparing nature versus urban (Beute & De Kort, 2019; Gidlow et al., 2016; Koivisto & Grassini, 2024; Laumann et al., 2003). The theories have also led to the development of new measures and tools, such as the PRS (Hartig et al., 1997) which is commonly used for measuring perceived restorativeness, as well as the adoption of physiological indicators of stress (heart rate, blood pressure, salivary cortisol) in research studies (Huang et al., 2021).

The two theories can be seen as distinct from one another with SRT focused specifically on stress reduction and ART concerned with the restoration of attentional capacity. Shortly after these theories were first introduced, a more integrative framework was developed to bring the two theories together (Kaplan, 1995). Here, more focus is placed on directed attention and how it plays a key role in coping with challenges and stress. Still, to the current day, the foundational theories of SRT and ART dominate the literature. As stated in Hartig's, (2021) chapter focused on going beyond the conventional narrative of SRT and ART, the two most cited articles in the Journal of Environmental Psychology are ones focused on these two key theories (Kaplan, 1995; Ulrich et al., 1991). Thinking beyond the conventional narrative and how resources can be depleted but this can go beyond stress and directed attention, Hartig (2021) posits two more theories regarding depleted social relations (relational restoration theory; RRT) and depleted community resources (collective restoration theory; CRT).

2.4.4. Epidemiological evidence on nature and health

In current epidemiological studies which explore nature's impact on health outcomes, the two theories are often invoked as either justification for exploration or as explanations for findings. Epidemiological evidence which has explored the relationships between nature and health will be examined next, however it is recognised that some of these studies included focus on 'blue space', which is beyond the scope and focus of this thesis.

A seminal exploratory study of over 10,000 Dutch adults who had lived at their residence for at least 1 year empirically tested the amount of greenspace and blue space within their living environment with self-reported health and well-being whilst controlling for socioeconomic and demographic characteristics (de Vries et al., 2003). The living environment was determined as a radius of within 3 km, and green and blue space coverage were calculated using geographic information system (GIS) and the National Land Cover Classification database. The level of urbanicity within a living environment was also categorised from 'very strongly urban' to 'non-urban', based on the number of households per square km. Their results showed that increasing proportions of greenspace in the neighbourhood were associated with a lower frequency of reported recent symptoms of illness, lower rates of self-reported poor health, and a lower odds of self-reported psychological distress. Additionally, subgroup analyses showed that the relationship between greenspace and health was stronger for less educated people, as

well as housewives and older people compared to the general population. The results of this study were specific to Dutch adults which suggests future research should be conducted across other countries as well as with different age groups.

Another larger scale study (N = 250,782) used multilevel logistic regression analysis and showed that the percentage of greenspace in a person's living environment (within a 1 km and 3 km radius around a person's home) also positively correlated with perceived general health (Maas et al., 2006). Whilst they found that all age groups significantly benefit from greenspace, older adults and youth seemed to benefit more from greenspaces in their living environment, compared to adults (Maas et al., 2006). The study was conducted using health data from a Dutch national survey which was collected from individuals across 104 general practices in the Netherlands, and the amount of greenspace was determined from the National Land Cover Classification database. The authors of this study note that selection effects may have influenced their results, such as selective migration whereby healthy individuals move to greener environments, however a strength of this study was its inclusion of participants from different age groups.

Since these seminal studies, more epidemiological studies have begun to focus on associations between neighbourhood greenspace and mental well-being more specifically. Firstly, several reviews have been conducted which have assessed the literature exploring nature, greenspace and mental health and well-being, and have reached differing conclusions. For example, Gascon et al., (2015) focused on green and blue spaces and specific long-term mental health benefits and conducted a systematic review which included 28 studies. The included studies had a range of longitudinal, ecological, and cross sectional study designs, and the majority of studies had been conducted in Europe, followed by USA and Oceania. The majority of studies used self-report questionnaires to assess mental health outcomes and suggested limited evidence for a causal association between residential greenness and adult mental health, and inadequate studies which included solely children. The authors concluded that a main limitation again was the heterogeneity of exposure measures used in the studies and not being able to conduct a meta-analysis due to inconsistent reporting and missing data.

Systematic maps have also been used to map the literature and are helpful in identifying gaps which warrant further investigation. For example, Collins et al., (2020) assessed 276 studies which have explored the link between greenspace and mental health, of which 124 were experimental studies and 152 had observational study designs. Similarly to a

previous review by Gascon et al., (2015), the majority of studies were from Europe and USA and lacked representation from low and middle-income countries. Some main conclusions from the review state that experimental studies often infer causality but use unrepresentative samples, and measures of greenspace are often in regard to quantity rather than quality. Whilst some experimental studies were represented, the majority of studies used an observational study design involving cross-sectional data where it is then not possible to understand whether there is a causal relationship between greenspace and mental health.

One of the first reviews to focus on 'mental well-being' specifically looked at studies which included a measure of greenspace and used a validated tool to measure mental well-being in adults (Houlden et al., 2018). The review consisted of 52 studies, which were mostly cross-sectional surveys conducted in Europe. A key contribution of this review was that studies were categorised based on characterisations of greenspace: (1) amount of local-area greenspace, most commonly the proportion of local areas covered by greenspace; (2) greenspace type; (3) views of greenspace; (4) visits to greenspace; (5) accessibility, and (6) subjective connection to nature. The quality of greenspace is often overlooked in research, and instead quantity is predominantly measured (Collins et al., 2020). Through their narrative synthesis, it was concluded that the amount of greenspace has positive associations between mental well-being, in particular with hedonic well-being, although more research is needed looking at both hedonic, and eudaimonic mental well-being. Further, limited evidence was found between mental well-being and associations with visits to greenspace, accessibility, and types of greenspace. Views of greenspace and connectedness to nature also lacked associations. This raises an important consideration in that a definition of exposure to greenspace varies across epidemiological studies which makes it difficult to draw conclusions and report generalisability. Whilst the terms for greenspace, nature, and natural environments are used interchangeably and different definitions for each are adopted, the same is similar for definitions of exposure and how exposure is measured (Houlden et al., 2018), and what contact with nature can mean (Frumkin et al., 2017). This is a very broad criteria which presents challenges for comparisons between studies and confusion in relation to benefits gained from disparate exposures which could then lead to inappropriate and ill-informed recommendations for policy and practice.

2.4.5. Nature-health frameworks

From extensive epidemiological and experimental evidence, frameworks have been developed in order to organise and map associations between nature and health and their potential underlying mechanisms. Additionally, these frameworks have been inspired by ecological models of public health which foreground the importance of ecosystems and the environment in influencing health outcomes (World Health Organization, 2016, 2020), for example the health map which was developed from and illustrates the determinants of health and well-being in the urban context (Barton & Grant, 2006; Whitehead & Dahlgren, 1991).

Firstly, a well-cited framework from environmental psychology which explains the connections between nature and health and well-being was presented by Hartig et al., (2014) (Figure 2.1). Here, the natural environment is sub-divided into type, quality and amount. Types, qualities, and amounts of nature are likely associated with kinds of contact someone has with nature. The connection between contact with nature and health and well-being may then be through several pathways. These pathways include air quality, physical activity, social cohesion, and stress reduction. Reciprocal relationships between each of these variables are also illustrated (double headed arrows) which suggest that each of these pathways are likely relate to each other. Additionally, two pathways go directly from the natural environment to air quality and stress, without individuals needing to come into contact with nature for this relationship to health to exist. It should be emphasised here that some pathways to health and well-being are thought to operate through direct contact with nature, such as engaging in physical activity in a greenspace and seeing more neighbours in a space which enhances social cohesion. Air quality can be improved by greenspaces mitigating air pollution, however this can happen regardless of whether individuals interact with nature or not. Similarly with stress, viewing nature in a simulated experience, such as photographs, videos or virtual reality (VR), can also provide stress relief (Liszio et al., 2018) without an individual having a real interaction with nature. Modifying variables (purple arrow) in the framework suggest that the kinds of contact that you have with certain types, amounts, and qualities of nature are likely influenced by how accessible they are, how safe they are perceived to be, what the weather is when visiting, and the societal and cultural context. Also, there can be influence from what age someone is, what their gender is, their socioeconomic status, occupation, and the societal and cultural context.

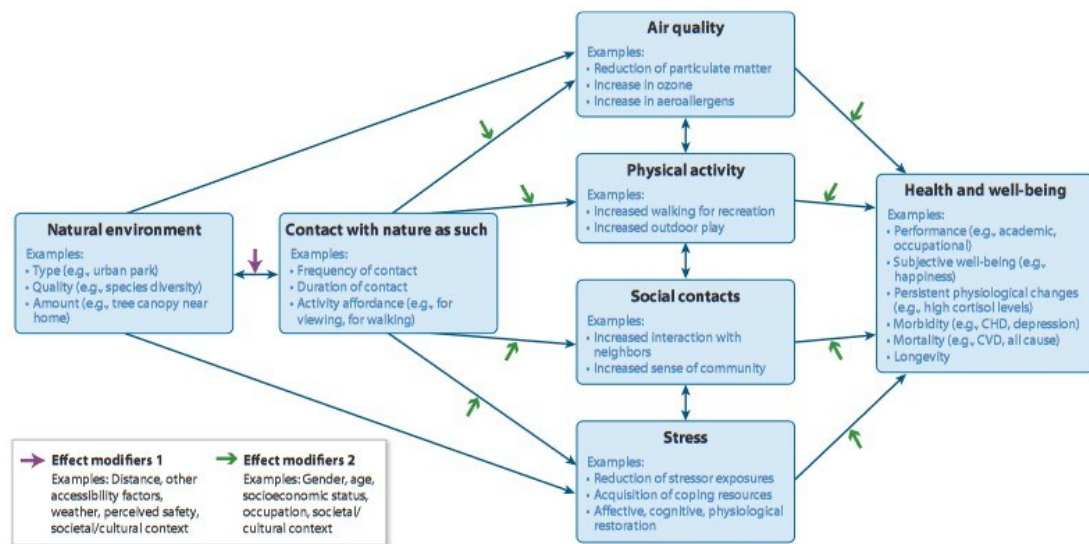


Figure 2.1. Nature and health framework from Hartig et al., (2014).

These pathways were further explored and three domains were created to categorise the pathways linking greenspace to health and focusing on general functions of greenspace (Markevych et al., 2017). These domains included reducing harm (mitigation), restoring capacities (restoration) and building capacities (instoration). Reducing harm can include reducing exposure to environmental stressors such as noise, heat and air pollution.

Restoring capacities can include restoring attention and psychophysiological stress recovery, which links back to the key theories of SRT (Ulrich, 1981) and ART (Kaplan & Kaplan, 1989). Finally, building capacities can refer to encouraging physical activity and facilitating social cohesion. Each of these three domains are covered by the four general pathways which were previously included (Hartig et al., 2014). A difference in this new model goes beyond just air quality in the reducing harm domain and encompasses all environmental stressors, such as noise pollution and reducing exposure to heat to combat the urban heat island effect (Voogt & Oke, 2003).

Another variation of Hartig et al's., (2014) framework was adapted by Nieuwenhuijsen et al., (2017). Consistent with Hartig et al's., (2014), this framework considers greenspace (type, quality, amount) and contact with greenspace (frequency, duration, activity) as pathways to health and well-being outcomes. The variation is in regard to mediating factors. As with Hartig et al., (2014), these consist of physical activity, stress, and social contacts. Additionally, this framework posits the biodiversity hypothesis and biogenics hypothesis as significant mediators. These refer to the benefits which can be gained from bacteria exposure and interference with cell signalling. In Hartig et al's., (2014) framework,

air quality was also included as a mediator. In Nieuwenhuijsen et al's., (2017) framework, however, it is under a broader category of environmental exposure reduction. As well as better air quality, this also includes factors such as lower temperatures.

Related, but novel, contributions also come from other existing frameworks (Marselle et al., 2021; White et al., 2020). Another framework integrates biodiversity specifically and states that biodiversity can influence human health via four domains (Marselle et al., 2021). These domains include the previous three stated by Markevych et al., (2017); reducing harm, restoring capacities, building capacities, but also extends the model by adding a fourth domain of 'causing harm' which can lead to negative health and well-being effects. Causing harm can include contact with wildlife that causes harm (e.g., snake bites, skin irritation from stinging nettles), exposure to infectious diseases (e.g., COVID-19, malaria), exposure to microorganisms beyond infectious disease (e.g., microbiome diversity), and increasing exposure to airborne allergens and volatile organic compounds (e.g., pollen). A key importance highlighted in the framework relates to distinguishing between objective and subjective biodiversity. This can be applied to greenspace whereby actual greenspace could be the amount of greenspace present in a residential area, as measured using the normalized difference vegetation index (NDVI), whereas perceived greenspace would be how much greenspace people think is in a residential area and could be measured using a self-report questionnaire.

A second related framework focuses specifically on blue spaces and how exposure to these types of spaces may benefit health and well-being (White et al., 2020). The framework is similar to previous frameworks but includes novel additions. Firstly, in relation to the first component of exposure, this is categorised into four types: proximity, indirect exposure, incidental exposure, and intentional exposure. These then lead onto the same three pathways of mitigation, instoration, and restoration (Markevych et al., 2017), and the same modifiers proposed in Hartig et al's., (2014) framework. One addition to this framework is that alongside human health and well-being, planetary health and well-being (e.g., pro-environmental behaviours) can also result from the same processes and pathways. A second addition are feedback loops which suggest that health and well-being impacts can engender support for societal, local, and personal actions and interventions, which can affect the process as a whole. A final addition in this framework recognises the concept of nature connectedness and includes it as a state (instoration) and trait (modifier) variable.

Amongst other socio-demographic variables, a key moderator in these frameworks is age (Hartig et al., 2014; Nieuwenhuijsen et al., 2017; Markevych et al., 2017; Marselle et al., 2021; White et al., 2020). Whilst included as an important modifier, limited research has focused specifically on age, particularly the experience of multiple ages of people in greenspaces. Another striking recognition is the focus placed on quantity of greenspace, or type of exposure to greenspace, but limited research included in this review has explored qualities of greenspace and specific properties of greenspaces which are important for health and well-being.

2.4.6. Nature and health in childhood and adolescence

The majority of research to date has focused on adult populations with limited studies including other age groups or taking an intergenerational approach. Research focused on children and adolescents use of greenspace has become more prominent due to the increased mental and behavioural problems in this age groups (Ogundele, 2018), as well as the decreased amount of time that this age group spend in nature and greenspaces compared to previous generations (Scott et al., 2022; Clements, 2004). The disconnection from nature can have consequences for well-being and development (Scott et al., 2022; Little & Wyver, 2008).

Systematic reviews have focused on mental health and well-being interchangeably in relation to children and adolescents (McCormick, 2017; Tillmann et al., 2018; Vanaken & Danckaerts, 2018; Zhang et al., 2020). Thirty-five articles were included in a review which focused on children and teenagers' (18 years old and younger) interactions with nature and quantitative measures of mental health (Tillmann et al., 2018). The majority of included papers were conducted in the UK, USA, and Canada, and the outcomes measured were categorised into emotional well-being, attentional deficit disorder/hyperactivity disorder, overall mental health, self-esteem, stress, resilience, depression, and health-related quality of life. Half of the papers included reported significant positive findings between nature and mental health outcomes, such as overall mental health, self-esteem, stress, resilience, depression, and health-related quality of life. However, the evidence was limited to mostly cross-sectional research designs and half of papers did not report any statistically significant results, which makes it difficult to reach a consensus.

Another review focusing only on children found that, of the 12 articles included, most reported positive associations between access to greenspace and mental well-being, for example, promoting attention restoration, improved memory and competence,

supportive social groups, and moderating stress (McCormick, 2017). The review included studies which had involved populations of 18 years old or younger and had been published between 2012-2017. Of the 12 included studies, one was a qualitative study and the remaining 11 were quantitative study designs. The qualitative study reported that students were able to find relief from stress, improve focus, and build confidence and social groups when learning and playing in areas of the school which included natural features, e.g., wood playgrounds, natural habitats, and gardens (Chawla et al., 2014). Interestingly, of the included studies, no measures included physiological biomarkers, unlike research which has included adults and often uses physiological measures (Corazon et al., 2019). Physiological measures can often be too invasive which may explain their less frequent use. Whilst a strength of this review was that both quantitative and qualitative study designs were included, it highlighted the lack of qualitative evidence. The single qualitative study provides depth and detail to the review which the quantitative studies otherwise lack.

Thirdly, the target sample for another review comprised of adolescent's (10-19 years) and their mental well-being and explored the impact of greenspaces (Zhang et al., 2020). A similar sized synthesis to McCormick (2017), the review encompassed 14 studies published between 2000-2020 and found several positive associations between greenspaces and measures of mental well-being. These included reduced stress, positive mood, reduced depressive symptoms, improved emotional well-being and mental health, and reduced psychological distress. The majority of included studies were cross-sectional and conducted in developed countries (e.g., USA, UK, Canada). Various covariates, modifiers and moderators were included in the analyses of the included studies of which the most common were sex/gender, age, race/ethnicity and socioeconomic status, however, no clear pattern in moderating effects were reported.

Both of the reviews by McCormick (2017) and Zhang et al., (2020) are limited in their size of synthesis (N = 12 and N =14 respectively), however this does highlight the scarcity of research which has focused primarily on younger age groups. More research is needed to understand the impact that greenspaces can have on children and adolescent's mental wellbeing. One specific recommendation from Zhang et al's., (2020) review stated that research is needed looking at the use of different types of greenspaces and the perceptions of features in these spaces. This could be explored using qualitative research, of which this study design was excluded from Zhang et al's., (2020) review and barely represented in McCormick's (2017).

Furthermore, Vanaken & Danckaerts (2018) conducted a systematic review which focused on outcomes including mental health problems, mental well-being, as well as developmental problems. Studies were included if they had focused primarily on children, adolescents or young adults. The included studies (N = 21) were from developed countries (Europe, North America, Oceania) and the majority had a cross-sectional design. The majority of the studies assessed greenspace exposure by residential neighbourhood greenness (e.g., NDVI). Of the included 21 studies, they found a significant amount of evidence showing a beneficial association between greenspace exposure and emotional and behavioural problems (e.g., hyperactivity and inattention), but suggested more research needs to look at confounding and mediating interactions. Finally, a recent systematic review and meta-analysis focused on cognitive functioning outcomes of children and adolescents (< 10 years and 10-19 years) after nature exposure (Nguyen & Walters, 2024). A total of 52 studies were included in the review of which 51 were included in the meta-analysis. Separate meta-analyses were conducted for correlational and experimental studies. The findings showed no association between nature exposure and cognitive functioning outcomes for correlational studies. However, for the experimental studies nature exposure had restorative and instorative effects, specifically for attention and executive functioning outcomes.

As shown by the outlined reviews, evidence shows support for exposure to greenspaces and benefits for children and adolescents mental health and well-being. This is an important field of research due to the influence that early childhood nature experiences can have on childhood development and later adult behaviour (e.g., pro-environmental behaviour) (Dankiw et al., 2020; Evans et al., 2018; Rosa et al., 2018). Striking evidence even proposes ‘nature deficit disorder’ which describes that children are spending less time outdoors than previously and this can lead to attention difficulties and increased rates of physical and emotional illness (Louv, 2008). There is a need for more evidence which explores the impact of natural environments on younger people’s mental well-being. In addition to the younger population, the older population can also benefit from exposure to greenspace and nature and this will be discussed next.

2.4.7. Nature and healthy ageing

Globally, people are living longer and the proportion of the world’s population over 60 years old between 2015-2050 will double from 12% to 22% (World Health Organization, 2022a).

And by 2030, 1 in 6 people in the world will be 60 years or older (World Health Organization, 2022a). These statistics call for ways of facilitating healthy ageing and one way to do this is through nature exposure and engaging in greenspaces (Duedahl et al., 2022).

Several nature-based studies have been conducted which target older adults health and well-being and these have been synthesised in an evidence map (Catissi et al., 2024). Twelve studies were included in the synthesis whereby ten were randomized controlled trials (RCTs) and two were systematic reviews. Exposures involved forest bathing, walking in natural environments and therapeutic gardens, and VR. They were predominantly conducted in the Northern Hemisphere. Overall, the evidence map showed support that nature-based studies significantly contribute to maintaining and enhancing functional abilities in older adults which can lead to improved health and well-being.

Research further highlights the benefits of greenspace across the lifecourse (de Keijzer et al., 2016, 2018; de Keijzer, Basagaña, et al., 2019; de Keijzer et al., 2020). Firstly, a systematic review synthesises long-term greenspace exposure and cognition across the lifecourse (de Keijzer et al., 2016). All studies included (N = 13) were observational study designs and involved populations of children, adults and older adults. Overall, the review concluded that there is suggestive evidence for a positive association between long-term greenspace exposure and cognition over the lifecourse, however the evidence is currently inadequate. Limited longitudinal studies were found, and heterogenous methods and outcome assessments made comparisons complex.

Several more longitudinal studies focused on long-term exposure to greenspace have been conducted which used data from the Whitehall 2 Cohort. One of these focused on associations with cognitive decline (de Keijzer et al., 2018) and three more looked at physical health outcomes including physical functioning (de Keijzer, Tonne, et al., 2019), metabolic syndrome (de Keijzer, Basagaña, et al., 2019), and progression of arterial stiffness (de Keijzer et al., 2020). Firstly, with cognitive decline, it was found that an increase in greenness (NDVI) was associated with slower cognitive decline over a 10 year follow-up period (de Keijzer et al., 2018). Moreover, increased greenness has been found to be associated with slower age-related decline in walking speed and higher baseline grip strength (de Keijzer, Tonne, et al., 2019). Proximity to natural environments was also associated with slower decline in walking speed and more beneficial in areas with higher compared to lower deprivation. Overall, the study concluded that higher residential greenness and living closer to greenspaces contribute to improved physical functioning in older adults. For longitudinal studies focused on health outcomes, including metabolic

syndrome and arterial stiffness, higher residential surrounding greenspace was found to be associated with lower risk of metabolic syndrome with middle-aged and older adults (de Keijzer, Basagaña, et al., 2019), and for arterial stiffness, no consistent associations were found with residential surrounding greenspace (de Keijzer et al., 2020).

As well as longitudinal studies, some qualitative research has also been carried out, although the evidence base again is limited. One qualitative study using walking interviews and aimed to explore how and why older adults relate to nature and how this can facilitate active healthy ageing (Duedahl et al., 2022). The study was conducted with 48 Danish citizens who were 55 years and older. The study reported complex conclusions including variation in engagement with nature in that some participants saw nature as enclosed and static, whereas others saw their engagement as a continuous unfolding of themselves and the world. Whilst this is an important start, more qualitative studies are needed which involve older adults and explores their relationship with greenspaces and their health and well-being

2.4.8. Summary

In summary, the current global mental health crisis is a huge burden of disease which needs urgently addressing (World Health Organization, 2024c). Key determinants of poor mental well-being include environmental factors whereby urbanisation has a significantly negative impact (Lederbogen et al., 2011; Ventriglio et al., 2021). On the other side, exposure to nature and greenspaces can be beneficial for mental well-being as they can allow for recovery from stress and restoration of attention, as theorised by two dominant theories: SRT and ART (Kaplan & Kaplan, 1989; Ulrich, 1981). Extensive epidemiological evidence has provided support for these beneficial effects (de Vries et al., 2003; Frumkin et al., 2017; Houlden et al., 2018), which have then led to several frameworks being developed which explain linkages through mitigation, instoration, and restoration (Hartig et al., 2014; Nieuwenhuijsen et al., 2017; Markevych et al., 2017; Marselle et al., 2021; White et al., 2020), and evidence exists around the impacts of nature on positive childhood and healthier ageing. There is a gap in the evidence which is the lack of research focused on younger and older populations and how age as a factor could impact the mental well-being benefits gained from exposure to greenspaces. Next, this literature review will discuss greenspaces within urban areas which are a common component of urban settlements and defined here as 'urban greenspaces' (UGS). With the majority of the population living in urban areas predicted to double by 2050, having access to

greenspaces is essential for mental well-being. UGS will be discussed in relation to different age groups and how this could moderate the benefits gained.

2.5. Urban greenspace and well-being

To recap, the definition of natural environments in the MENE survey (Natural England, 2020) describes natural environments to include 'greenspaces in towns and cities (e.g., parks, canals), the countryside (e.g., farmland, woodland, hills and rivers), and coastline (e.g., beaches, cliffs)'. This thesis will focus just on greenspaces in town and cities, or 'urban greenspaces' (UGS).

As with mental well-being and greenspace, there is no universal definition for UGS in the literature. Definitions differ across disciplines and between studies which makes it difficult to interpret findings, and to compare findings across studies and disciplines. For this thesis, the definition used for UGS is, 'all urban land covered by vegetation of any kind. This can also include small water bodies such as ponds, lakes or streams ("blue spaces")' (World Health Organization, 2016). This definition includes both private and public spaces, however for this thesis, only public spaces will be considered due to the size and scope of the project. The definition of public spaces for this thesis is taken from Francis et al., (2012) who describe public spaces as, 'the meeting or gathering places that exist outside the home and workplace that are generally accessible by members of the public, and which foster resident interaction and opportunities for contact and proximity' (Francis, Giles-Corti, et al., 2012; Oldenburg, 1989). The focus of this definition is also on public access instead of public ownership. These types of places can include for example, parks, community gardens, school playgrounds, and recreation areas. Elements such as private gardens, and green roofs or walls, are often included in a definition of UGS (Cvejić, et al., 2015), however they did not meet the criteria of the chosen definition for being a public space or a meeting or gathering place which can foster resident interaction.

UGS, like vegetation more generally, provide numerous ecosystem services. These include improved air quality (Konijnendijk et al., 2013), reduced air pollution (Diener & Mudu, 2021; Huang et al., 2021), reduced noise pollution through buffering from vegetation (Kang, 2014; Veisten et al., 2012), increased cooling and reduction in the urban heat island effect (Chang & Li, 2014), opportunities for nature conservation and increased biodiversity (FarinhaMarques et al., 2011; Lizée et al., 2012), mitigation against flooding (Qin, 2020; Semeraro et al., 2021), and improved soil quality (Peng et al., 2012; Semeraro et al., 2021). UGS can more directly promote human well-being through some

of the mechanisms illustrated by the earlier described frameworks (Jabbar et al., 2021; Krefis et al., 2018). Potential risks and access barriers to UGS will next be discussed before highlighting numerous reviews and empirical studies provide support for the link between UGS and well-being (sub-section 2.5.2).

Whilst there are multiple benefits from UGS, there are also associated risks and disservices which are less represented in the literature. A recent report divides the risks associated with UGS into four main categories: injuries death and safety, pollen and allergies, vectors and zoonotic diseases, and infections and antimicrobial resistance (World Health Organization, 2023). Crime and perceived safety are an important factor which can impact the benefits gained from UGS (Maruthaveeran & van den Bosch, 2014). Fleming and colleagues showed that whilst greater access to greenspace was associated with better life satisfaction, this effect was not present if the space was perceived as unsafe by the residents (Fleming et al., 2016). Furthermore, the risks associated with UGS are also more prominent for certain disadvantaged populations, including those of lower socioeconomic status, women, black and minority ethnic groups, people with disabilities, and older adults (World Health Organization, 2023). For example, more than 20% of parks in deprived neighbourhoods are associated with higher levels of psychological distress (Ambrey et al., 2014). In relation to women specifically, numerous studies have highlighted that women and girls feel unsafe in UGS, such as parks (Barker et al., 2022; Polko & Kimic, 2022). Feelings of fear expectancy, high levels of disgust, and preference for modern comforts are all reasons for avoidance of greenspaces (Bixler & Floyd, 1997). Direct negative experiences such as being stung by insects (e.g., bees/wasps) or becoming lost, or indirect experiences such as hearing stories from friends or in the media, can all influence fear and give reason to avoid visiting greenspaces (Bixler & Floyd, 1997; James & Embrey, 2001). Conflicts also arise from the presence of dog faeces and tension between dog owners and non-dog owners (Chen et al., 2022; Gaunet et al., 2014).

2.5.1. Barriers and facilitators to use of urban greenspaces

When discussing UGS for mental well-being, consideration must be given to the factors which may facilitate use or be a barrier. Firstly, taking a broad approach, a narrative review by Lee et al., (2015) reported extensive research which had focused on the characteristics of UGS which are likely to influence its use, including accessibility, quality, facilities, attractiveness, and security. A key conclusion of the review was that it is more

likely that the functionality of greenspace rather than its character which translates to reported well-being benefits e.g., for exercise or sociocultural activities, which future studies should consider.

Looking more at specific factors, research has highlighted the importance of social factors (Lo & Jim, 2010; Seaman et al., 2010), the size of greenspaces (Mitchell et al., 2011), and focused on quality over quantity (Francis, Wood, et al., 2012). One key factor which has been found as influential for use of UGS are social factors (Lo & Jim, 2010; Seaman et al., 2010). For example, physical characteristics of UGS can encourage social interactions, such as the inclusion of seating and play equipment, and other factors such as dog walking which can act as a catalyst for interaction with other dog walkers (Roe & McCay, 2021). A qualitative study conducted in Hong Kong explored public perceptions towards UGS (Lo & Jim, 2010). Structured interviews were conducted with residents from four residential communities (old-core public housing, old-core residential, suburban residential, new-town public housing) who spoke about their attitudes towards and preferences for greenspaces, visiting patterns, and assessment of neighbourhood quality. Across the different communities, many findings centred around social factors as being important for visitation: being a place for neighbourly interactions which lead to a better relationship with the older residents and being places for family activities. It was concluded that social qualities were more important than physical properties in impacting visitation. Another qualitative study also reported the importance of social cohesion at a community level and the amount of integration and inclusion of the community (Seaman et al., 2010). And these feelings can mitigate barriers such as anti-social behaviour. These results were found through 24 in-depth interviews conducted in the UK. This study also reported more in-depth nuances such as the presence of unsupervised older children can be seen as a barrier to others using the greenspace.

There are other factors which can be a hinderance and inhibit social cohesion. Crime, lack of maintenance and cleanliness, antisocial behaviour, inaccessibility, lack of amenities, and neighbourhood conditions can all hinder UGS use and therefore social cohesion in these spaces (Clarke et al., 2023). Interestingly, some studies have shown that a lack of people in UGS or lack of social relations can lead to fear in these spaces (Burgess et al., 1988; Maruthaveeran & van den Bosch, 2014). Focusing on gender specifically, women feel safer in parks which are well-used and busier due to the increase in passive surveillance and opportunity to seek help (Barker et al., 2022). However, for girls, other people such as groups of teenage boys make the space feel unsafe because of their dominance over the space and risk of harassment (Barker et al., 2022). The

evidence suggests that no matter what an UGS offers in terms of facilities and opportunities, this can all be overridden by the other people in the space and whether they are intimidating. It is essential that more research is conducted looking at the social aspects of UGS and how other people being present in a space can influence the experience, use and benefits gained. This is essential because it can underpin whether people visit UGS at all.

2.5.2. Epidemiological studies in urban greenspaces and well-being outcomes

As with broader nature and greenspace research, numerous epidemiological studies have investigated the relationship between UGS and health and mental well-being. To synthesise this evidence, scoping and systematic reviews are prominent. One scoping review included 25 studies of which most were cross-sectional designs (Callaghan et al., 2020). The review was focused on mental health but included mental well-being and well-being in the search terms. In the included studies, mental health was generally measured using self-report tools. Twenty-three of the studies reported mostly positive associations between greenspace characteristics and mental health (Callaghan et al., 2020). Of the studies included, definitions of greenspace were varied and vague and, similarly to previous reviews, studies were predominantly from Europe. Another scoping review including 201 studies looked more specifically at exposure to greenspace in preventing anxiety and depression amongst young people aged 14-24 years (Reece et al., 2021). The included studies were mostly from North America or Europe and adopted observational or experimental designs. The review highlighted the under-representation of low-middle income countries and lack of ethnic diversity in study populations. This scoping review informed a subsequent systematic review which explored whether green and blue spaces prevent anxiety and depression in young people living in urban settings (Bray et al., 2022). The review included 48 studies and concluded that walking or being in a greenspace can improve mood and state anxiety. Studies also suggested that physical activity, social interaction, and mindfulness can mediate the relationship between greenspace and mental health.

Alongside reviews, research studies are presented here which have looked at different aspects of UGS and mental well-being. Firstly, some studies focus on access (Bertram & Rehdanz, 2015). Survey data was assessed to explore how UGS can affect well-being of residents in Berlin. UGS was measured as a combination of spatially explicit data and spatially highly disaggregated GIS data. The self-report study found an inverted U-shaped

effect for the amount and distance of UGS on life satisfaction. The results suggested that the ideal amount of greenspace in a 1 km buffer of the residential area is 36 ha.

Moreover, another study moved beyond focusing on access to UGS and instead focused on visits (Ma et al., 2019). The study utilised regression analysis to look at Beijing residents' well-being and UGS. They found that the more residents participated in UGS (e.g., frequency of visits), the higher their well-being. This effect was highest for those that lived between 1-5 km away from a park or public greenspace and over 10 km away (inverted U effect). Additionally with visitation to UGS, structural equation modelling has shown that residents who have visited UGS within the previous two weeks had reported higher positive and lower negative emotions and higher life satisfaction than non-visitors (Hong et al., 2019). This data came from 400 residents in South Korea who completed an online survey. Whilst this study provided novel findings in relation to UGS visits, it was limited by its sample of adults 20-59 years old. More research focusing on younger and older populations would enable comparisons across the lifecourse.

Other studies have also gone beyond looking at solely access as an exposure variable and looked more in-depth at qualities and attributes of UGS. Wood et al., (2017) looked at the presence, amount and attributes of UGS in new greenfield neighbourhood developments and the mental health of residents (N = 492). They found that the number and total area of greenspace were significantly associated with better mental well-being. Positive mental health was associated with parks which had a nature focus, as well as characteristics dedicated to recreational and sporting activities. As with other cross-sectional studies, causation cannot be inferred from the findings which limits the conclusions made.

Studies have also looked at perceptions of UGS. For example, a longitudinal study conducted in two waves explored perceptions of quantity of UGS and mental well-being (Cleary et al., 2019). Regression analysis showed at both time points that perception of UGS quantity was significantly positively associated with psychological well-being. Participants perceiving an increase in the amount of greenspace were more likely to report an improvement in their psychological well-being. This study was novel in that it went beyond looking at objective qualities or access to UGS, but instead focused on the importance of perceptions of these spaces. In addition to this study, research also has looked broadly at perceptions of UGS and identified eight sensory dimensions: serene, space, nature, rich in species, refuge, culture, prospect and social (Grahn & Stigsdotter, 2010). Their results suggested strong associations between the refuge and nature dimensions and stress and needing a restorative environment. They concluded that

refuge, nature, species richness, and low or no presence of a social dimension is the most restorative environment for stressed individuals. This study added to the evidence base by focusing on the importance of perceptions of restorativeness, as well as mental well-being. An interesting finding from this study is the importance of the social aspect of UGS. This follows on from the previously described research which suggests the social capacity of a space can be positively impactful on visitation (Lo & Jim, 2010; Seaman et al., 2010). Whilst Grahn & Stigsdotter (2010) suggest that limited social opportunities can be restorative, opposing research supports the importance of UGS as being areas which can facilitate social cohesion by creating space for social interactions and therefore be beneficial, for example, in reducing loneliness which is a problem in urban and rural areas (Astell-Burt et al., 2022; Corcoran & Marshall, 2017). It should be noted that this aspect of UGS is less researched in the field and warrants further investigation.

2.5.3. Urban greenspace experimental designs and health and social well-being outcomes

In addition to these broader reviews, studies have also been conducted with a methodological study design. For example, a meta-narrative review looked at UGS studies and a range of factors including health, well-being, social, environmental and equity effects, or any known influencing factors of these outcomes (Hunter et al., 2019). The results suggested the provision of UGS to not be sufficient in improving health, the promotional efforts for UGS are crucial, and also highlighted the need to research UGS in a more holistic way. Another systematic review was conducted exploring public UGS characteristics and well-being components (Reyes-Riveros et al., 2021). In the included 153 studies, greenspace characteristics were grouped into: structure, biodiversity, naturalness, and others. Similarly, well-being was grouped into health, security, good social relations, and freedom of choice and action. Overall, the number of greenspaces and the percentage and size of vegetation cover benefited well-being across all groups, especially health.

Some studies have involved specific age groups, such as older adults (Benton et al., 2021). A study was conducted in the UK which was a prospective controlled naturalistic experiment and involved making low-cost physical changes (e.g., tree planting, increased signage) to several UGS to see if there was an effect on well-being behaviours or usage. The results showed no significant impact and participants reported that the study was not substantial enough to be noticed.

A systematic review was conducted in order to assess the effectiveness of studies to encourage physical activity in UGS (Hunter et al., 2015). The review included 12 studies which involved experimental studies to promote physical activity in UGS. The majority of

studies adopted quasi-experimental, controlled, pre-post designs and were conducted in the USA. Whilst there was supporting evidence of built-environment only studies in supporting physical activity, there was also evidence of the impact that promotional studies could have on physical activity changes. A recommendation of the review was for research to give more consideration to the social environment in which these studies are developed.

2.5.4. Qualitative and case study research on urban greenspaces and health and social outcomes

Whilst the majority of reviews and studies conducted which look at the mental well-being effects of UGS have been quantitative, some have also considered qualitative methods, although these are less common. Twenty-one studies were included in a review of qualitative studies, which mostly consisted of studies using semi-structured interviews (McCormack et al., 2010). The qualitative findings showed that attributes such as safety, aesthetics, amenities, maintenance, and proximity are important factors for park use. They also found an important role for the social environment and its inter-connections with the perceptions of the physical environment. From these reviews, it is clear that more qualitative research needs to be conducted as it can provide a more in-depth understanding of the benefits of UGS for well-being.

Some qualitative studies have been conducted, however they are limited in the literature. For example, semi-structured interviews have been used to explore park users' health and well-being and association with various UGS (Nath et al., 2018). The findings from the study suggested parks as being a sufficient space for recreation and leisure facilities (e.g., jogging), as well as being a place with physical activities for children. The majority of participants also stated that the physical and leisure activities in the parks had a positive impact on stress reduction and overall well-being. Similarly, using interviews and an adult sample, Weimann et al., (2019) identified six categories which were important pathways between UGS and well-being: promoting activities, supporting social contacts, stimulating sensory impressions, providing a retreat, offering ways to influence and creating a sense of coherence. Walk-along interviews have also been employed in a study in New Zealand which explored the significance of parks in the lives of urban residents (Noe & Stolte, 2023). Interviews with 21 residents highlighted that parks provide a deep engagement with nature and provide restorative benefits by allowing for escape from stressful city life, proximity and frequency of use lead to a sense of ownership, and that parks are mainly used as spaces for social activities. These

studies provide encouraging findings for well-being but more qualitative research is needed in the field in understanding the properties of UGS which are beneficial for well-being, as this method can provide an in-depth exploration which can help untangle the complex interactions.

Another qualitative study implemented focus groups to explore perceptions of UGS in the UK (Gidlow & Ellis, 2011). Adults and young people (12-15 years) were involved in the focus groups and the data was analysed using thematic analysis to identify themes. There was a need for more facilities and community engagement, and adults had safety concerns which could be alleviated by more lighting and improving visibility. Both adults and young people spoke about anti-social behaviour as a barrier to use and the importance of living close to UGS.

As well as qualitative study designs, case study research also provides valuable insight into UGS and well-being (Du et al., 2021). Using Shanghai in China as a case study, focus was placed on investigating features of UGS which influence health and well-being (Du et al., 2021). The paper reported that accessibility to lawns, water bodies and fitness facilities were important for overall health and well-being. Low levels of noise and vegetation diversity also had positive effects on mental well-being. Finally, calm, relaxation, vigour, fitness, and proactivity can increase with the addition of greenways and walkways.

A salient finding from the few qualitative studies which have been conducted is the importance that UGS have for facilitating social contact, interaction and cohesion. Peters and colleagues also supports that urban parks are more inclusive greenspaces than non-UGS and that they promote social cohesion (Peters et al., 2010). Additionally, qualitative research studies provide support for greenspace in reducing loneliness (Birch et al., 2020; Neal et al., 2015; Swierad & Huang, 2018). For example, Swierad & Huang (2018) conducted 20 interviews and found that being in parks allowed for connection to family, loved ones and friends, community and neighbourhood, self, and nature. Overall, it is clear that the social aspects of UGS are important to visitors and something which can be explored further.

2.5.5. Urban greenspace across age groups

As presented in the Restorative City Framework, a restorative city is comprised of seven typologies: the inclusive city (designing spaces for all people), the green city (maximising exposure to greenspace), the blue city (maximising exposure to water), the sensory city

(involving multiple senses to benefit health and well-being), the neighbourly city (designing spaces to support and maintain social networks and interactions), the active city (focusing on physical activity, mobility and accessibility for all people), and the playable city (including features in cities which promote play, creativity and expression) (Roe & McCay, 2021). This thesis aims to explore the socio-demographic factor of age, which is an important consideration for having an inclusive city. Whilst it is crucial to understand how UGS can be beneficial for well-being, it depends on whether all ages are able to benefit.

Whilst longitudinal research is limited, some exists, and can provide strong evidence for associations compare to cross-sectional studies. For example, a longitudinal study spanning 9 years was conducted in Australia which aimed to explore the relationship between public greenspace and mental well-being of 40-65 year olds (at baseline) (Carver et al., 2024). Using a linear fixed-effects model, the study concluded that mental well-being increased with greenspace exposure, suggesting a beneficial longitudinal association. Another study looked at the psychological benefits of exposure to UGS over 2 years (Tariq et al., 2024). The study recruited 500 urban residents who were assigned to an exposure group or control, whereby the exposure group were encouraged to have regular exposure to UGS. Those in the exposure group showed a reduction in stress compared to the control group and a higher increase in psychological well-being. Whilst longitudinal research does well to provide a long-term perspective, the results are correlational which do not suggest causality.

Looking more specifically at age as a factor which can be an impactful covariate and modifying factor, the literature will now be synthesised into aspects of UGS which can be impacted by age; access, frequency of use, preferred activities to do in UGS, and general preferences.

2.5.5.1. Access

Firstly, age can influence access to UGS. With children, barriers exist in accessing UGS (McCormick, 2017). For example, children may lack access due to long walking distances to UGS (Aggio et al., 2015), and safety concerns from parents (Clements, 2004). Children's spatial behaviours are influenced by their parents behaviour and opinion towards UGS use (Kytä et al., 2018). However, schools can be important environments in order to access UGS and therefore provide easy access for children (Chawla et al., 2014; McCormick, 2017). For older children and adolescents, having access to a greenspace of choice is more beneficial than being able to access the closest greenspace (Vanaken & Danckaerts, 2018).

Naturally, older children have greater accessibility to UGS than younger children (Arvidsen et al., 2022), due to increased independence. Whereas with older adults, a study found older women were more likely to be constrained in their park use due to fear of crime, lack of park companionship, poor health, and no method of transport to get to parks (Scott & Jackson, 1996). Furthermore, using a cross-sectional design, a study reported that the prevalence of mental health issues reduced in relation to the amount of UGS in the area (Lee & Lee, 2019). The study was conducted in Korea and looked at stress levels and symptoms of depression in elderly urban residents whilst also calculating the ratio of UGS.

2.5.5.2. Frequency of use

When looking at frequency of use, it has been reported that younger and older people often spend more time in or near their home (de Vries et al., 2003). This is supported by research which found older adults more likely to be non-visitors of parks, and people over 50 years old were less likely to have visited a park in the last year (Payne et al., 2002). Additionally, children are more likely to visit greenspaces more frequently if their parents are frequent visitors (Kytä et al., 2018; Skar et al., 2016). When comparing younger children and adolescence, it has also been outlined that being outdoors in greenspace declines in adolescence as compared to early childhood (Arvidsen et al., 2022; Braun & Dierkes, 2017). Moreover, adolescents and young adults will not use greenspaces if they perceive them to not be safe or offer anything in terms of facilities or quality (Dias et al., 2019; Lyons et al., 2022; Mertens et al., 2019). And finally, frequency of greenspace use is predicted by the number of types of greenspaces which are perceived to be within close proximity to home (Arvidsen et al., 2022).

2.5.5.3. Preferences

Age can also influence preferred activities that people want to undertake in greenspaces. For example, older adults are more likely to prefer recreation to conservation than younger adults (Payne et al., 2002). Furthermore, more older adults take part in nature-related activities than younger people (Ode Sang et al., 2016). However, as age increased, the less the greenspaces were being used for physical activity. One study also found that there is a stronger relationship between activity levels and living near parks in younger (18-34 years) and older (55+ years) age groups (Kaczynski et al., 2009). Respondents aged 50-65 years older were more likely to visit small UGS for rest and restitution compared to 15-29 year olds (Peschardt et al., 2012). They also found that the older people were, the less likely they were to visit small UGS in order to socialise, compared to younger people. Older adults also tend to prefer less dense vegetation in

urban parks (Bjerke et al., 2006), as well as nature related activities and landscapes aesthetics (Ode Sang et al., 2016). On the other hand, in regard to children, one of the preferred environments of children are natural environments (Evans, 2006; Flouri et al., 2014). Furthermore, for children, active recreation features and organized sports programs are reasons to visit UGS (Loukaitou-Sideris & Sideris, 2009). Likewise for older children and teenagers, UGS are spaces to socialize with peers and get involved with physical activity (Loukaitou-Sideris & Sideris, 2009).

2.5.5.4. Focus on intergenerational well-being

Despite numerous studies on greenspace and well-being, there is limited intergenerational research which has considered multiple age groups simultaneously. Some research has begun to consider multiple age groups but this perspective is limited in the field. For example, Sundevall & Jansson, (2020) conducted walking interviews with children, adolescents, and older adults in Sweden to explore specifically the management of UGS. Researching multiple populations simultaneously would allow the identification of common components of UGS that are beneficial for a wide range of users with the potential to bring them together. This could allow for more inclusive designs of UGS and recognition that age groups should not be considered and researched separately to each other. Here, intergenerational is defined as, ‘creating relationships between individuals of different generations’ (Cushing & van Vliet, 2016; Nelischer & Loukaitou-Sideris, 2023; Pain, 2005). Thang & Kaplan (2012) differentiate between multigenerational public spaces which, ‘accommodate the physical and psychological needs and abilities of various age groups’, whereas intergenerational public spaces can ‘additionally foster meaningful interaction, communication, engagement, and connection among generations’.

2.5.6. Multi-sensory urban greenspaces

A brief note should be made in regard to UGS being multi-sensory spaces. So far, empirical evidence looking at the benefits of UGS lacks focus on the impact that multi-sensory components of UGS can have on psychological and physiological well-being. Studies have looked at individual sensory components (e.g., sounds of nature) (Hedblom et al., 2017; Song et al., 2023; Uebel et al., 2021), rather than studying multiple senses concurrently. The visual sense predominates in nature-health studies and is supported by several scholars including Roger Ulrich who states that vision is the most important sense (Ulrich, 1983). Additionally, Brown (2017) states that “the bodies of green space users are often invoked in environment-health studies as little more than vessels for eyes that

look effortlessly across outdoor spaces in ways that seem to lead to well-being". In research, the visual sense is either explicitly through the use of imagery/videos in experimental studies, or implicitly through the interpretations made in both psychological and epidemiological research as to what components or experiences of nature engender better mental wellbeing. Experiences of these spaces in reality are multi-sensory. Individual sensory components (e.g., visual, auditory, olfactory, haptic) in greenspaces can all have a positive impact on well-being (Brown, 2017; Hall et al., 2013; Ratcliffe et al., 2013; Ratcliffe, 2021a; Rickard & White, 2021; Van Houwelingen-Snippe et al., 2021; Zhang et al., 2021). However, limited studies tend to look at a combination of sensory stimuli and the multi-sensory effects they can provide for well-being. Importantly, individuals with sensory impairments need to be able to access the benefits offered by exposure to UGS and this is not possible if spaces are researched, and therefore designed, with only one sensory input in mind (Bell, 2019).

Studies which have involved multiple sensory stimuli, have often paired together vision and sound (Deng et al., 2020; Liu et al., 2019; Pheasant et al., 2010). Alongside visual stimuli, auditory stimuli are easy to create and use and are low-cost. Additionally, research has suggested that visual and auditory information can reinforce one another or exhibit interference (Deng et al., 2020; Song et al., 2018). Environment sounds are particularly important in research due to their effects on health and well-being. Exposure to environmental noise, or 'noise pollution', can lead to detrimental effects on health and wellbeing, including cardiovascular disease, cognitive impairment, sleep disturbance, tinnitus, and general annoyance (Andringa et al., 2013; World Health Organization, 2011a). The WHO defines environmental noise as 'noise emitted from all sources except for noise at the industrial workplace' (World Health Organization, 1999). A main burden of environmental noise relates to road traffic noise, with reports in West Europe stating at least one million healthy life years are lost every year due to traffic-related noise (World Health Organization, 2011a). This is a major public health concern knowing that road traffic noise is particularly prominent in urban areas, where most populations reside. Additionally, this may be worse for vulnerable groups and groups of lower socio-economic status, due to lower housing prices being located near noisy roads (World Health Organization, 2011a), although this may change due to the increased production and use of electric cars (Jansen & Petrova, 2023).

Whilst urban areas are mostly associated with negative and harmful noise, UGS have been found to reduce noise and be a space for natural sounds to occur (Alvarsson et al., 2010; Gidlöf-Gunnarsson & Öhrström, 2007; Viollon et al., 2002). It is important to also

consider which sounds can be beneficial, not only which are detrimental. As argued by Ratcliffe (2021), there is a greater need to understand sounds in and beyond urban areas which bring positive experiences. A growing body of research highlights the positive impact that nature sounds can have, including birdsong, running water, and rustling leaves which can be beneficial for restoration and well-being (Alvarsson et al., 2010; Hedblom et al., 2017; Ratcliffe et al., 2013, 2016). For example, studies have demonstrated that when participants listen to the sounds of nature after a stressful event, there is activation of parasympathetic activity which is an indicator of bringing the body back to a restful state (Alvarsson et al., 2010; Annerstedt et al., 2013). Furthermore, one study showed that individual differences could have an impact on the experiences which individuals have with UGS, including how restorative they find the sounds (Hedblom et al., 2017). They found that women and older adults reported higher levels of calmness when listening to birdsong and rustling leaves, than men and younger participants (Hedblom et al., 2017). In addition to this, research has shown that the impacts of natural soundscapes on perceived restorative potential are highly moderated by memories (Smalley et al., 2023). This was found through a randomized controlled experiment which exposed participants (N = 7636) to a nature scene which had one of four acoustic soundscapes. The addition of natural sounds was associated with greater feelings of restorative potential and this effect was significantly greater for individuals who had positive experiences which were stimulated by the experience.

Whilst the evidence presented here is mostly separated, the sensory experience is generally perceived as a whole and is hard to untangle. Despite the well-documented benefits that natural sounds can provide, it is essential to recognise that sounds co-exist and whilst hearing birdsong at a park, there may also be the sound of nearby road traffic present. Urban and natural sounds are usually intermixed and neither is there a space which is entirely silent (Hedblom et al., 2017). For the research presented in this thesis, auditory stimuli will be considered in addition to the visual experience of UGS.

2.6. Virtual reality as a research tool

Until now, the literature discussed is mostly in relation to UGS which have involved real exposure and viewing an actual space. Whilst this can be seen as the most ecologically valid setting for research, experimental research setups provide a means of isolating variables and establishing causal relationships; potential confounds can be controlled for and we can therefore infer what effects are directly attributable to nature of the variations on natural stimuli we might use as independent variables. For example, it is

difficult to physically manipulate actual UGS to isolate variation in some quality of these environments, e.g., the number of people present, the weather, or the amount of biodiversity.

While meta-analytic evidence supports the idea that ‘actual’ exposure to nature confers greater positive impacts on affective outcomes than simulated counterparts (Browning et al., 2020), a vast amount of research still employs such experimental designs using pictures and videos for the reasons presented above (McMahan & Estes, 2015), drawing on seminal research establishing the impacts of viewing such stimuli on stress relief and attention restoration (see sections 2.4.1 and 2.4.2). Such experimental paradigms also extend to more immersive depictions of nature stimuli that allow both for the same level of experimental control, but also qualities such as physical exploration and sensory richness such as virtual reality; an increasingly used methodological tool in such research (Blascovich et al., 2002; Chan et al., 2021; Roberts et al., 2019). Moreover, the findings can inform studies for people in institutionalised settings such as hospice patients (Artmann et al., 2017), prisoners (Nadkarni et al., 2021; Söderlund & Newman, 2017), or individuals with sensory difficulties (McAllister et al., 2022).

2.6.1. Experimental research on VR nature and health and well-being outcomes

Virtual exposure, or simulations, can occur in different form including images or photographs, videos, 360-degree videos, and extended reality (XR). XR encompasses all technologies that blend the real world with the digital one and includes virtual reality (VR), augmented reality (AR), and mixed reality (MR). Simulations can be visual projections of real or fictionally created environments (e.g., computer generated) that can consist of multiple sensory aspects (Browning et al., 2021).

Several reviews of the literature have been conducted which have evaluated the evidence of virtual nature and well-being (Frost et al., 2022; Lee et al., 2022; Liang et al., 2024; Spano et al., 2023). One review highlighted the most common outcomes of studies using virtual nature which included mood, stress and restorativeness (Spano et al., 2023). Findings generally describe a positive effect of virtual nature on its users (Spano et al., 2023), although sometimes this can be more about alleviating negative emotions rather than inducing positive ones (Lee et al., 2022). There is also support for 3D virtual environments being comparable to real-world nature and that designs in VR can be transferable to real-world settings which result in similar physiological effects (Liang et al., 2024). Other reviews have found that evidence is mixed, with some studies reporting positive outcomes after virtual nature exposure (e.g., decrease in negative affect),

however other studies report contrasting results (Frost et al., 2022). There is suggestion that more research is needed looking at virtual immersion in nature and the impact on well-being (Frost et al., 2022). Studies also have to have adequate power, specific samples and identify best practices and include physiological measurements (Liang et al., 2024; Spano et al., 2023).

Virtual nature was found to be particularly beneficial for well-being during the COVID-19 pandemic (Lau et al., 2023; Zabini et al., 2020). For example, after a 3-week study involving 2D videos of nature, participants (N = 56) reported significant changes in psychological stress levels after exposure to nature compared to baseline (Lau et al., 2023). Participants showed increased levels of happiness, comfort and relaxation. However, no significant differences were identified for any physiological measures (heart rate, heart rate variability, blood pressure). This finding is in line with other studies which report mixed results regarding physiological outcomes (Frost et al., 2022; Nukarinen et al., 2020).

So far, few studies have used virtual exposure and focused specifically on UGS (Gao et al., 2019; Hedblom et al., 2019). One study used 360-degree photos shown through a VR head-mounted display (HMD) to investigate the restorative effects of multi-sensory spaces (Hedblom et al., 2019). After viewing a virtual park and forest, they found a significant reduction in stress and highlighted the importance of the olfactory stimuli (nature and city odours) in this effect, rather than visual. The effects were not found for the urban condition (dense urban area). Moreover, another study used VR to investigate physiological and psychological restoration and individual preferences for several environments: grey space, blue space, open green space, partly open green space, partly closed green space, and closed green space (Gao et al., 2019). Panoramic photographs of the environments were shown through VR glasses, whereby no significant differences were found for physiological measurements (electroencephalography; EEG) across any environment. Whereas for psychological measurements, there were significant differences in negative mood between the environments. The partly open green space had the most positive effect on negative mood and the closed green space had the worst. From this study, it is important to recognise the importance of including different types of measures (psychological and physiological) as they can lead to conflicting findings.

2.6.2. Proliferation on VR technology and its drawbacks

Arguably the most immersive tool for virtual exposure to environments includes the use of VR. VR environments, also referred to as Immersive Virtual Environments (IVEs), are most often shown through HMDs which block the vision of external reality and project a 360-

degree virtual world. Motion sensors are also a part of HMDs which can determine the movement and direction of the body of the user. HMDs, such as the Oculus Quest (Meta), Vive (HTC) and PlayStation VR (Sony Interactive Entertainment) are increasingly more affordable and accessible for the general public which allows virtual environments to be easily viewed from home. However, there are some barriers to the use of VR, for example needing a fairly high level of computer skills proficiency to use a device (White et al., 2018).

But the most reported limitation of viewing VR is the side effect of cybersickness (Kim et al., 2005; Oh & Son, 2022). When using a VR HMD, cybersickness can occur due to the disconnect in what the eye sees and the body feels. This is often in relation to motion, with the symptoms of cybersickness explained by sensory conflict theory and the symptoms occurring most like those for motion sickness: dizziness, headaches, nausea, and disorientation (Kennedy et al., 1993; Reason & Brand, 1975). Despite the limitations associated with VR technology, a new avenue of research has developed which utilises its benefits.

2.6.3. Coupling VR with physiological measurement

Several studies involving virtual methods of exposure have included physiological indicators in their outcome measurements. One physiological measure included has been EEG (Chang et al., 2008; Gao et al., 2019; Grassini et al., 2022; Seiz et al., 2023; Ulrich, 1981; Zhang et al., 2021). One study used spectral analysis and reported increased alpha waves over the central brain when participants viewed natural scenes (3 minute videos) compared to urban and neutral (no environment) scenes (Grassini et al., 2022). In addition to measuring brain activity, environments were also rated in terms of relaxation, whereby participants rated the nature scenes as most relaxing. Another study used VR to show participants (N = 21) a vacant vegetated site and again as a reimagined greenspace (Seiz et al., 2023). Measurements include alpha and beta brain activity using EEG, as well as subjective responses of the PRS. The EEG results were mixed in that no significant differences were observed with alpha frequencies, but beta frequencies indicated a gender effect. Beta power spectral density decreased for men when viewing the redesigned space, whereas it increased for women. Moreover, Gao and colleagues investigated physiological responses via EEG to several urban environments (varying in amount of green, blue, and grey space) (Gao et al., 2019). Interestingly, EEG measures showed no significant differences across the different environments but psychological

measures (attention, mood) did suggest that as the preference for natural environments increases, so do the benefits for well-being. EEG has also been used as an outcome measure for studies using VR as a tool for relaxation and showing participants relaxing views of nature (Zhang et al., 2021). Consistent differences were identified in alpha and gamma waves after participants viewed the relaxing scenes.

As well as EEG, physiological measures including skin conductance have been adopted. A key study looking at virtual UGS and physiological stress was carried out by Hedblom and colleagues (Hedblom et al., 2019). They recruited 154 participants to view one of three 360degree VR environments (park, urban forest, urban built-up environment). Environments involved multi-sensory stimuli (visual, auditory, olfactory) and physiological stress recovery was measured via skin conductance after exposure. They reported significant stress reductions after exposure to the park and forest environment, but not the urban, and their results provided support for olfactory stimuli as being a better facilitator for stress than visual stimuli. Another study utilised skin conductance as a measure of relaxation (Knaust et al., 2021). They also included measures for heart rate and perceived relaxation. The study compared 360-degree nature videos displayed via a VR HMD with the same videos on a flatscreen computer monitor. Skin conductance significantly decreased when viewing the stimuli through the HMD and on the computer, compared to control. And heart rate showed no significant differences between technology conditions. Due to the mixed results, this study recommended future research compare VR HMD with flat-screen stimuli.

As well as skin conductance, VR research has also included measures of heart rate (pulse), heart rate variability and blood pressure (Blum et al., 2019; Chan et al., 2021; Hooyberg et al., 2023; Yu et al., 2018). For example, one study looked at VR forest and urban environments in relation to restoration, employing both physiological and psychological measures (Yu et al., 2018). In relation to the physiological measures, it was shown that systolic blood pressure and heart rate decreased with time regardless of environment. However, significant effects were found for their psychological measures. The results of this study support the need to include subjective and objective measures in research as they can show varying results. Another study by Chan and colleagues used Unity (Unity Technologies, 2024) to create VR environments to investigate whether vertical greenery in an urban environment can buffer against stress, using heart rate variability as a psychophysiological measure (Chan et al., 2021). Their results showed support for greenery on city building as being effective in buffering psychophysiological stress. It is important that research continues to include physiological measurements of

well-being as well as other simultaneous measures such as psychological, subjective measures and qualitative outcomes.

2.7. Research gaps and questions

This thesis has three aims which inform three overarching research questions. The first aim of this thesis is to explore broadly what multi-sensory properties of UGS are beneficial for mental well-being. Whilst there is extensive evidence supporting the benefits that UGS can have for well-being, studies tend to focus on one age group at a time. Limited knowledge exists which takes a more intergenerational approach and considers multiple age groups and whether there may be similarities or crossover between groups and whether benefits can be gained across all ages. This thesis aims to explore which specific properties of UGS are beneficial and whether this is the same across different ages. The overarching research question which addresses this aim is:

RQ1: What multi-sensory properties of urban greenspaces are beneficial for mental wellbeing for different age groups, and what are the commonalities across generations?

The second aim of this thesis focuses on the exposure methods in this field and how new and current methods, specifically VR, are being used as a research tool for exposure. Manipulating stimuli in experimental studies requires control and laboratory settings, where VR can be used, playing to its strength of providing an immersive environment which does not require outdoor exposure. This thesis aims to explore this further to look at whether this exposure method is feasible and acceptable, particularly when focused on the topic of this thesis: UGS and mental well-being across all age groups. The overarching research question which addresses this aim is:

RQ2: Is virtual reality (VR) a feasible and acceptable tool for researching the multi-sensory benefits of urban greenspaces for mental well-being?

The final aim of this thesis was developed following the results of the first 3 empirical studies (Chapters 3,4,5) and focuses on the social aspect of UGS and how this can impact the experience of UGS. Limited experimental research has looked at the social aspect of UGS and how other people being present can impact well-being outcomes, and so this thesis aims to add new knowledge. Additionally, this aim contributes to answering RQ1

by considering age as a modifying factor, as well as using VR as a research tool, informed by the answer to RQ2. The overarching research question which addresses this aim is:

RQ3: How does crowding in urban greenspace impact social and perceived restorative outcomes?

Chapter 3: Qualitative study

Title

How properties of urban greenspaces shape mental well-being across age groups: A qualitative study

Reference

Reece, R., Elliott, L., Bray, I., and Bornioli, A. (2024). How properties of urban greenspaces shape well-being across age groups: A qualitative study. *Wellbeing, Space and Society*. 7, 100206.

3.1. My contribution

The work presented in this chapter is published in the peer-reviewed journal, *Wellbeing, Space and Society*. This study was funded by the Economic and Social Research Council (ESRC), as part of my South West Doctoral Training Partnership (SWDTP) studentship undertaken at The University of the West of England (UWE), Bristol, UK. An acknowledgment for this study being included in this PhD thesis is stated in the original publication and all authors involved gave permission for this research to be included in this thesis. As lead author, I was responsible for conceptualising this study, designing the study methods, conducting data collection and analysis, and writing up. All other authors supported and enabled this research throughout.

3.2. Overview

This chapter presents the first empirical study included in this thesis which aimed to gain an in-depth understanding about how properties of urban greenspaces contribute to mental well-being. In addition to this, I explored similarities and differences across age groups and how properties facilitated social interaction across these groups. Rather than looking at age groups individually, the study looked holistically at how properties can impact mental well-being across the lifecourse. The study adopts an exploratory research design using qualitative methodology and utilises semi-structured interviews across four age groups (adolescents, young adults, adults, older adults) to answer overarching thesis research question 1, 'What multi-sensory properties of urban greenspaces are beneficial for mental well-being for different age groups, and what are the commonalities across generations?'. From the study, four themes are identified which were common across all age groups and answer thesis research question 1; UGS can provide a sense of escape; there are practical needs surrounding access and contact with UGS; UGS being a space to share with other users; and the importance of seasonal multi-sensory components of UGS.

Unlike the other empirical studies presented in this thesis (Chapters 4,5,6), this is the only study to adopt a fully qualitative design and methodology. This was so to provide an initial in-depth analysis of how properties of urban greenspaces contribute to mental well-being, before then leading onto several experimental studies (Chapters 4,5,6), which adopt a narrower focus. There was scope in this thesis to take forward one theme from this qualitative study to inform the focus of the final experimental study (Chapter 6). The theme 'being a space to share with other users' was chosen and the final experiment (Chapter 6) studies the social aspects of urban greenspaces and how other people being present in these spaces can impact mental well-being and social connectedness.

Due to the word limit of this journal article, extra details regarding the methods are presented in [Appendix 1](#).

3.3. Chapter 3 research questions

RQ1: What common properties of UGS shape mental well-being similarly across age groups?

RQ2: How do UGS support social interactions across different age groups?

3.4. Abstract

The prevalence of poor mental health among younger and older generations is rising. Urban greenspaces (UGS) can provide mental well-being benefits and are used by all ages, so it is important that these spaces provide benefits across the life course. So far, studies tend to focus on one age group and lack focus on properties of these spaces which shape mental well-being across generations. Our aim was to explore what properties of UGS can shape mental well-being across age groups and to what extent are UGS for social interactions across age groups. Qualitative semi-structured interviews were conducted online with 20 participants in four age groups: adolescents, young adults, adults, and older adults. Interviewees were asked about visits to UGS, preferences for multi-sensory components, and how spaces shape their mental well-being. Using thematic analysis, four themes were identified which were common across all age groups: UGS can provide a sense of escape; there are practical needs surrounding access and contact with UGS; being a space to share with other users; and the importance of seasonal multi-sensory components. Whilst findings showed that there are properties of UGS which are valued across multiple ages, differences were also revealed regarding interactions across ages. By researching qualitatively across ages, the complex similarities and differences between ages can be understood. Future research should also explore interactions between age groups as well as the views of non-users of UGS and their reasons for not visiting UGS.

Keywords: urban greenspace; well-being; interview; qualitative research

3.5. Introduction

There is a current mental health crisis amongst youth (Thomson & Katikireddi, 2018), in addition to a growing older population with increasingly poorer mental health (United Nations Department of Economic and Social Affairs, 2013; World Health Organization, 2022a). Further, living in poor environmental and social conditions can lead to poor mental health, as well as increased morbidity and mortality rates (Becker & Kleinman, 2013). Mental health has a significant impact on individuals and communities and is associated with high economic burden globally (Doran & Kinchin, 2019). In 2022, mental health problems cost the UK economy at least £118 billion with 10.3 million reported cases of mental ill-health in one year (McDaid et al., 2022). One risk factor for mental health problems is urbanization and a move from rural to urban living (Ventriglio et al., 2021). By 2060, it has been estimated that 80 % of the world's population will be living in

megacities (Bhugra et al., 2019). One suggestion to reduce the stressful factors associated with urban living is to improve access to green areas (Ventriglio et al., 2021).

Urban greenspace (UGS), such as parks, green corridors, and residential greenery, are used by all age groups and can provide multiple benefits for mental health (Callaghan et al., 2020; Corazon et al., 2019; Lee & Lee, 2019; Reece et al., 2021). Roe & McCay, (2021) outline these specific benefits as: (a) protection for mental health (as nature exposure as a child can reduce the risk of later mental health problems); (b) improved cognitive health including increased memory recall and mental alertness; (c) increased social well-being including social interaction and place attachment; (d) improved stress regulation; (e) improved emotional well-being including reduced depression and anxiety; and (f) the management of mental health problems including symptom management of severe mental health problems. This wide evidence base has led to the expansion of 'green prescribing', encouraging people into nature to help those with mental health problems to manage their symptoms (Roe & McCay, 2021; van den Berg, 2017; Wood et al., 2023). Going out into UGS could be a non-pharmacological option for addressing the burden of mental health at a population level.

Multiple age groups visit UGS, and the mental well-being benefits gained have been extensively documented (Callaghan et al., 2020; Derkzen, 2012; McCormack et al., 2010). However, research shows that preferences for particular properties of UGS vary according to age group (Ayala-Azcárraga et al., 2019; Nordh & Østby, 2013; Rivera et al., 2021; Veitch et al., 2020a, 2020b, 2021). For example, children have different needs in a park than adolescents, adults, and older adults (McGrath et al., 2015). For children in Australia, there is emphasis on the presence of play equipment, water features, sports courts, and picnic areas (Veitch et al., 2020b). Similarly, adolescents in Australia aged 13–18 years old enjoy the presence of sports features, playgrounds, seating, picnic areas, open space, good maintenance, and accessible locations (Rivera et al., 2021). Further, university studies in Norway describe 'lots of grass', flowers, and water features as being features which are restorative and is defined as aiding in renewing depleted psychological resources (Hartig et al., 1997; Nordh & Østby, 2013). Adult users of nine various sized parks in Mexico City were quantitatively surveyed where results showed that well-being in an UGS is influenced by favourable social interactions and trustworthy users of a space (Ayala-Azcárraga et al., 2019). They also found that spatial components (size, accessibility, and distance to the park) were important predictors of use of the park

and self-reported well-being. They concluded that properties of parks can influence well-being if they are focused on favouring social interactions, rather than being aesthetically pleasing. Further studies found that older adults aged 65+ years old stated that a well-maintained, peaceful, and attractive area encouraged visits, as well as the presence of shady trees, birdlife, other people, seating, facilities, and water features (Veitch et al., 2020a, 2021).

The findings of previous literature tend to focus on specific age groups, while there seems to be a lack of research aimed at exploring differences and commonalities across several age groups. One study by Sundevall & Jansson, (2020) in Sweden did incorporate park users of different ages (children, adolescents, and older adults), however their main focus was on management of UGS and creating a multifunctional inclusive park space. Using walking interviews, they found similarities across ages in relation to appreciating contact with nature, social places for their own age groups, clean and safe areas, and having a variety of atmospheres within the park. It is important to focus research across multiple age groups because UGS are used by all ages and so need to be explored in an inclusive way which considers opinions across the life course.

Researchers have typically invoked two key theories when discussing associations between experiences of UGS and health and well-being outcomes: Attention Restoration Theory (ART) (Kaplan & Kaplan, 1989), and Stress Recovery Theory (SRT) (Ulrich, 1983). Firstly, ART posits that there can be recovery in attentional fatigue through the components of 'being away', 'extent', 'soft fascination', and 'compatibility' (Kaplan & Kaplan, 1989). Whilst all four of these components can also be found in urban spaces, ART states that they are more common in natural spaces. Overall, these components need to be perceived by individuals in order for an environment to be restorative. Moreover, the psycho-evolutionary theory, or SRT, states that being in a natural space can help recover from stressful situations (Ulrich, 1983; Ulrich et al., 1991). This theory explains that psychological stress recovery involves a positive change in emotional state, and physiological recovery relates to a change in parasympathetic nervous activity (Ulrich et al., 1991). Further, more recent frameworks have emphasized the importance of use of greenspace on the causal pathway to health benefits (Hartig et al., 2014; Nieuwenhuijsen et al., 2017). It is important to understand what all age groups want and need from UGS so to encourage use which can then lead to health benefits.

Going beyond the conventional narrative of theories of restoration, Hartig, (2021) presents new theories which describe (1) the restoration of relational resources between close social groups (relational restoration theory; RRT) and (2) the restoration of social resources in a larger community or population (collective restoration theory; CRT). Behaviours can be viewed at the level of a smaller group (RRT), or a wider community (CRT), and depletion and restoration can also occur at these levels. These theories are important to recognise as people visit UGS as individuals as well as in social groups of varying sizes and types (e.g., different ages). If UGS can address the needs of the community, they could help restore depleted resources held within smaller groups and larger communities. A better understanding of shared perspectives among diverse community members on the properties of UGS which could enable such restoration is therefore required.

So far, studies have tended to focus on one age group meaning there is limited intergenerational research in the field. Despite some initial studies, there is a gap in the literature regarding interactions across UGS users of different ages. Here, the term 'intergenerational' is used in the same way as in a review by Nelischer & Loukaitou-Sideris, (2022), defined by Pain, (2005) as relating to intergenerational practice. As opposed to multi-generational, intergenerational practice focuses on creating relationships between individuals of different generations (Cushing & van Vliet, 2016; Nelischer & Loukaitou-Sideris, 2023). Taking a policy and practice approach that aims to promote social inclusion and cohesion, and health and well-being across generations, there is a need to understand what physical characteristics and patterns of use are important to users, as positive perceptions of these can explain the links between UGS and social cohesion (Clarke et al., 2023; Jennings & Bamkole, 2019; Wan et al., 2021). It is well documented that social contacts and having increased social cohesion are important mediators in the relationship between greenspace and health and well-being (Cattell et al., 2008; Hartig et al., 2014; Rios et al., 2012). Therefore, understanding how UGS and their properties can shape such intergenerational interactions is required. A further aim of this study is to investigate social interactions across different age groups within UGS. This is particularly important to look at, as some previous literature around UGS has shown there can be conflicts (Groshong et al., 2020; Mak & Jim, 2018). For example, adults self-excluding themselves from UGS due to the presence of unsupervised, unfriendly younger people and potential anti-social behaviour (Seaman et al., 2010).

Another gap is regarding multi-sensory properties of UGS. Research focused on the benefits of UGS tends to concentrate on vision, with some arguing sight as the most important sense when it comes to experiencing landscapes and influences on health (Velarde et al., 2007). Not only can this approach be problematic for individuals with sight impairments, if spaces are researched and designed with only one sensory input in mind (Bell, 2019), but studies show that other sensory properties can also have a positive impact on well-being (Grahn & Stigsdotter, 2010; Hall et al., 2013; Ratcliffe, 2021; Van Houwelingen-Snippe et al., 2021; Zhang et al., 2019). In fact, UGS have been described as places which are perceived in multiple sensory dimensions and that perception should be viewed as a holistic experience (Abraham et al., 2010; Bell, 2012; Grahn & Stigsdotter, 2010; Herranz-Pascual et al., 2019). However, limited research has examined a combination of sensory stimuli in UGS and the multi-sensory effects that they can provide for mental well-being. Multi-sensory perception can affect the restorative effect of an UGS, which is shown through a theoretical framework developed by Zhang et al., (2019) and applied to an urban park in China. The framework explains how visual, auditory, and tactile perceptions are linked directly to the restorative effects of parks, as well as being mediated through emotional response and behavioural activities. Similarly with smells, the olfactory pleasantness of a space has been found to be linked with perceived restorativeness and can be just as meaningful as visual contact with nature (Martínez-Soto et al., 2021).

Participatory approaches which amplify the public's voice are key to the success of UGS design projects which benefit the mental well-being of diverse communities. It is important that all ages have access to UGS in order to benefit their mental well-being, acknowledging that each age group may have different needs. This aligns with a global movement which recognizes the diversity in cities and is moving towards designing age-friendly, child-friendly, and overall inclusive urban spaces (Brown et al., 2019; Fitzgerald & Caro, 2014; Roe & McCay, 2021). For example, with 'active ageing', where there is the aim to enhance quality of life and create opportunities for older adults in relation to health, security, and participation (World Health Organization, 2013). Interactions across age groups can contribute to active ageing and be highly important (Fitzgerald & Caro, 2014). In the literature, a systematic review by Levy-Storms et al., (2018) recommended that opinions of older adults should be included in urban park design as they have specific needs in regard to properties of UGS. Also, children have particular needs for a space and some projects are involving children in community greening projects (e.g., in Canada) and co-designing of spaces as it has been shown children have a strong desire to

shape their own environments (Campbell & Musa, 2018). By involving all of the community, it allows for the design of spaces with the user's needs as a main focus and for the community to take ownership of a space. Qualitative research is particularly well-suited to this aim as it allows for involvement from the community, with people being able to share their in-depth opinions about their experiences of UGS. A qualitative approach, such as individual interviews, can uncover detailed insights which quantitative methods alone cannot achieve.

The aim of this study was to explore how properties of UGS shape mental well-being across age groups. It is important to identify the commonalities across ages and in particular what multi-sensory properties of UGS are important for multiple ages. Furthermore, the aim of this research was not to establish a comprehensive set of greenspace correlates of mental well-being among different generations, but instead to understand how properties of UGS contribute to shaping mental well-being across ages to inform UGS design. By involving participants across multiple age groups, this study will contribute to the literature and provide an element of novelty. For the current study, the following research questions are proposed; (1) What common properties of UGS shape mental well-being similarly across age groups?, and (2) How do UGS support social interactions across different age groups? In order to address these aims and research questions, a qualitative semi-structured interview study was conducted.

3.6. Methods

3.6.1. Participants

The study was approved by the University of the West of England's Faculty Research Ethics Committee ([Appendix 2](#)). A total of 20 participants (n females = 14 (70 %); median age = 25 years old; age range = 12 to 80) were purposively sampled in Bristol (UK) across four age groups: adolescents 11–16 years old, young adults 17–24 years old, adults 25–64 years old, and older adults 65+ years old. Five participants were recruited for each age group. Additionally, two more participants were recruited in the adolescents age group for the purpose of piloting. Most participants were White British, with two being White Other (non-British), and one participant of Pakistani ethnic background. Due to the range of targeted age groups, participants were recruited through multiple pathways (Table 3.1).

Organisations relevant to the age groups were contacted and asked to advertise the study to their organisation members. The only eligibility criteria for participants were that they were regular users of UGS, which was defined as visiting UGS at least once a week for leisure. This was necessary so that participants would be able to discuss their experiences of using these spaces. Participants reflected on visiting a range of UGS including parks, playing fields, cycle paths, allotments, school playgrounds, community gardens, and woodlands near their homes (Table 3.2).

Age group	Recruitment strategy
Adolescents (11-16 yrs)	People in Health West of England (PHWE) Young People's Advisory Group (YPAG)
Young adults (17-24 yrs)	The University of the West of England's psychology participant pool
Adults (25-64 yrs)	The University of the West of England's psychology participant pool, snowball sampling
Older adults (65+ yrs)	Age UK Bristol, Bristol Old People's Forum, snowball sampling

Table 3.1. Recruitment strategy for participants in each age group.

Pseudonym	Sex	Age (yrs)	Age group	Ethnicity	Type of UGS visited
Nathan	M	12	Adolescents	White British	Park
Amber	F	14			Park
Paige	F	14			Park, fields
Sophia	F	16			Park, fields
Olivia	F	16			Park, fields
Alisha	F	18	Young adults	Pakistani	Cycle path, park
Aaron	M	18		White British	Park, streets
Claire	F	20		White British	Park, woodland
Nicole	F	22		White British	Cycle path, park
Thomas	M	23		White Other	Park, woodland
Harry	M	28	Adults	White Other	Park
Bethany	F	31		White British	Cycle path, woodland
Melanie	F	55		White British	Park
Caroline	F	56		White British	Park, school playing field
Steve	M	60		White British	Allotment

Esther	F	72	Older adults	White British	Community garden
Julia	F	72			Park, woodland
Dawn	F	72			Community garden, park
Elizabeth	F	75			Park
Simon	M	80			Playing field

Table 3.2. Participants profiles.

3.6.2. Procedure

Semi-structured interviews were conducted between September and December 2022. Volunteers interested in the study initially contacted the researcher via the email provided in the study advert. Participants then received a participant information sheet outlining the full details of the study ([Appendix 4](#)). After confirming a suitable day and time, participants joined a link to a Zoom call where the interview was conducted. Before commencing the interview, participants provided informed consent online via Qualtrics ([Appendix 3](#)). For adolescent participants (minors), additional verbal consent from a parent or guardian prior to the interview was an ethical requirement. Participants were given the opportunity to ask any questions regarding the study. All participants that took part were identified with a pseudonym (Table 3.2). Interviews were audio-recorded and automatically transcribed through the Zoom software. Participants were rewarded with a voucher or a university course credit (university students) for taking part. Once the transcripts had been edited for accuracy, audio recordings were destroyed. The open-ended questions asked participants about their visits to UGS, what components they like and dislike about the space, how the spaces impact their mental well-being, what sensory components they notice in these spaces, whether they visit UGS with other people, if they mix with people of different ages when visiting UGS, as well as their reasons for visiting and what their hypothetical ideal UGS includes ([Appendix 5](#)). Semi-structured interviews were chosen as they are suitable for exploring topics that people have personal circumstances to, allowing them to elaborate on their experiences through open-ended questions (Braun & Clarke, 2013).

Additionally, participants were asked to verbally state their age, gender, and ethnicity at the beginning of the interview so that the findings could be contextualised (Table 3.2). It was important to pilot the interview questions with the adolescent age group in order to check the language was understandable. Interviews were conducted remotely using the

software Zoom and lasted between 30 min to 1 hour. Online interviews were adopted due to uncertainty around the COVID-19 pandemic and risk of transmission.

3.6.3. Analysis procedure

After transcription, the datasets were analysed using thematic analysis (TA) (Braun & Clarke, 2006). TA was adopted due to its flexibility in identifying patterns of meaning in any type of data (Braun & Clarke, 2013). This was ideal in the current study as participants discussed various types of UGS they visited. All analysis was conducted using NVivo software. The first stage of analysis involved familiarisation with the data by re-reading all transcripts and becoming immersed in the data. Coding was then conducted using a bottom-up approach (inductive coding). This approach was taken so that codes were not dictated by pre-conceived ideas, expectations, and theories (deductive coding), but instead were solely generated based on what participants had said during their interview. TA and this coding approach allowed for a deep dive into the data without any presumptions and for the meaning to come out once the data was being coded. Further, it allowed for the identification of similarities and differences across the age groups and for themes to be identified across groups. After coding was complete, codes were grouped based on age groups. As the aim of this research was to explore commonalities across age groups, themes were formulated from the codes that were only present across all age groups. A similar method has been conducted previously in a study looking at categories across age groups (Sundevall & Jansson, 2020). Initial and finalised themes were discussed between all authors.

3.7. Results

Four main themes were generated on the commonalities across all age groups: adolescents, young adults, adults, and older adults (Table 3.3, [Appendix 6](#)). The first theme is that UGS can provide a sense of escape from everyday life. A second theme illustrates the practical needs surrounding access and visits to UGS. The third theme is about social cohesion and sharing a space with other UGS visitors. A fourth theme explains the importance of seasonal multi-sensory components in an UGS. Alongside the four common themes, there were also some important differences regarding interactions across different age groups in UGS. These will be highlighted at the end of the results, after description of the four common themes.

Theme	Sub-theme	Sample codes
1. UGS provide a sense of escape.	1.1. Spaces need to be big enough. 1.2. Spaces within a space.	Crowdedness impacts well-being and visits. Spaces need to be large enough for everyone. Getting away from people. Preference for large open spaces. Various environments within a space. Different routes through the space. Nature is a place to explore. Spaces are inclusive.
2. Practical needs for visiting UGS.	2.1. Spaces need to be accessible.	Living in close proximity to greenspace. Accessibility needs. Driving to access greenspace. Pathways are important.
	2.2. Weather dependency. 2.3. Safety concerns.	Bad weather is not a deterrent to going outdoors. Preference for dry weather. Visit greenspace more during summer. Visits are weather dependent. Lighting impacts visits. Interactions with strangers. Safety concerns.
3. Sharing a space with others.		Social cohesion. Meeting new people. Enjoy listening to other people. A space to meet a variety of people.
4. Seasonal sensory components.		Appreciation for seasonal changes. Smell of spring. Multi-sensory enjoyment of flowers. Water is relaxing.

Table 3.3. Table of themes and sample codes.

3.7.1. UGS provide a sense of escape

Interviewees from all age groups explain that UGS provide a sense of escape from everyday life. This theme is divided into two sub-themes which describe how an UGS can provide a sense of escape; (1) the spaces need to be big enough, and (2) there needs to be different types of space within the greenspace. Firstly, interviewees explained to provide a sense of escape from everyday life, spaces need to be physically large enough to accommodate this by avoiding over-crowding, so that users have the ability to get away from other visitors in the space. Multiple interviewees, including Olivia, speak about visiting UGS with the aim of getting away from other people:

"I think definitely something that would put me off [...] if it was busy. If there were a lot of people there and it didn't really feel like you were getting away from like the busyness of everyday life." (Olivia, 16 yrs.)

By having a large enough space, it means that even if there are a lot of visitors, everyone is not crowded next to each other. Whilst some interviewees described how an over-crowded UGS would impact their visit, for others, it was a reason to avoid a space altogether:

"If it's too much and too busy then I prefer to go somewhere else." (Melanie, 55 yrs.)

Secondly to size, UGS allow for a sense of escape by having different spaces within the space itself. Interviewees across age groups were opposed to open bare fields but instead preferred a space which had varying environments within it which made it intriguing:

"You're not always in the same space, you can travel through different areas and not just walk through an open field. You can go through the open field and then be by the lake and then up by the woods. I guess it makes it more interesting and less boring." (Aaron, 18 yrs.)

Having a changing environment with areas that are more 'wild', allowed for exploration of nature within the space, which was especially important for Sophia:

"It feels kind of like you're an intrepid explorer or something. I think I quite like having a wild bit (of the space) because it almost feels like it's there for you, it feels like you're the one exploring it." (Sophia, 16 yrs.)

Further, different routes through a space allowed for variation in walking, and the freedom to move in a way which was different to being in an urban space:

“There are paths and stuff, but I don’t always stick to them. I might go through the grass, go find a tree and suddenly I am able to move exactly the way I want to move. Which isn’t usually possible in the city.” (Harry, 28 yrs.)

It was clear from Harry’s account that an urban city space felt constricting, whereas being in his local park allowed for him to move through the space how he wanted. This allows individuals to express themselves how they want and use the space in a way which is best for them. Building upon this, variation in a space meant that multiple visits to an UGS were different and new experiences could be had:

“...they’ve got all sorts as you’re walking around to make it so that everytime we go you can find something new.” (Julia, 72 yrs.)

3.7.2. Practical needs for visiting UGS

A second theme common across all age groups was about the practical needs for visiting UGS. This theme describes the physical attributes of an UGS which are important and is broken down into three sub-themes; spaces need to be accessible, safety concerns, and weather dependency. Visits to UGS increase when there is good accessibility. Interviewees stated that spaces need to be accessible, whether that was living close by or needing physical pathways within the space. Firstly, interviewees described the importance of living near greenspace which made it is easy to access without being reliant on transportation:

“On a regular basis I normally would just go somewhere close by that I can walk to, because it’s just easier, and I’m not like sort of relying on a bus, or my mum to take me.” (Olivia, 16 yrs.)

Further, Claire described pathways as a positive aspect of her local greenspace and further emphasised the importance of these features for wheelchair users and push chairs:

“It’s got a nice tarmac path all the way through the middle, so it makes it more accessible for the push chair or people in wheelchairs. It’s great because you can go off the path with the dogs but if you’ve got people who need it to be flatter, they can also enjoy it.” (Claire, 20 yrs.)

The sub-theme of weather dependency occurred across all ages however, opinions were varied. For most interviews, bad weather was not a deterrent to going outside, as quoted by Melanie:

“The weather doesn’t put me off at all, I still go [laughs]. Even if it’s raining, I’ve still got my umbrella, wellies, the dogs got his coat on, and off I go.” (Melanie, 55 yrs.)

Additionally, whilst bad weather did not stop visitors from going to UGS, interviewees did experience the space differently depending on the weather. Numerous participants preferred visiting on a sunny day, but Sophia identified inclement weather as heightening the naturalness of the space:

“It is nicer on a sunny day I’ll say that, but even when it is raining, it’s still quite nice to be out in nature on your own, kind of experiencing the weather and I appreciate the naturalness of it.” (Sophia, 16 yrs.)

Sophia thus appreciated the wildness of nature and the naturalness of her surroundings. The inclement weather enhanced her experience and produced an increased feeling of wildness. The final sub-theme here is concerns for safety. All ages spoke about it as a factor which influences the spaces they visit and at what time of day. Quite broadly, Nicole and Elizabeth shared safety concerns about walking alone. For example:

“When it comes to stuff like parks or greenspaces... sometimes I don’t feel as safe walking by myself.” (Nicole, 22 yrs.)

Focusing on physical properties of a space, UGS were avoided in the dark due to the lack of lighting and fear of conflict:

“When it’s getting dark, and they feel a bit eerie and ominous. I don’t actually feel very comfortable at all. I would rather take a street where there are shops and street lights and perhaps more people. Just because I don’t want to have to deal with any kind of conflict.” (Harry, 28 yrs.)

3.7.3. Sharing a space with others

A third theme identified was about sharing UGS with other visitors. On one side, interviewees spoke about being in an UGS with the aims of being away from people and actively avoiding interactions with strangers. For example, Paige said:

“Sometimes a dog owner might stop and talk to me. Apart from that, I don’t go out of my way to talk to people.” (Paige, 14 yrs.)

On the other hand, visiting an UGS was an opportunity to meet a variety of new people. It can also be a space that is ‘common ground’ and somewhere people can meet on equal terms:

"It brings together people from several different areas, it's sort of an apex, there's several different sub-areas and we meet on equal terms. There's a bit of mutual exploration." (Dawn, 72 yrs.)

Interviewees unveiled that their experiences differed when visiting UGS alone compared to visiting with others. Specifically, Claire stated that visiting alone was a more peaceful experience:

"When you go on your own, you get that slightly more peaceful feeling." (Claire, 20 yrs.)

3.7.4. Seasonal sensory components

Finally, the fourth theme identified was regarding the seasonal multi-sensory components of an UGS. Interviewees discussed various multi-sensory components of the spaces they visited; however, they were in relation to the season they were visiting in and expecting. The changing seasons influenced the number of visits throughout the year, with some participants preferring to visit during the summer months due to the better weather, like Olivia:

"...(to visit) especially in the summer and when the weathers nice. It's nice to go and sit and have a picnic and chat (with friends)." (Olivia, 16 yrs.)

Whereas other interviewees preferred to visit in spring to see the regeneration of plants and the smell of cut grass, or autumn for the colours of leaves. Caroline described spring as her favourite time of the year for visiting her UGS:

"I think my favourite season is spring. Because everything is shooting and you get the nice bright coloured green leaves on the trees and it all looks fresh and new and everything is shooting and... especially on a nice blue-sky day, it's lovely. So, I think spring is my favourite time of the year." (Caroline, 56 yrs.)

Other noticeable sensory components included hearing birds and running water:

"I hear all of the birds. There's something about the birds, the noise as well as the wind in the trees and it's to do with my emotional well-being and physical wellbeing because I'm out there actually walking." (Julia, 72 yrs.)

"I think it's kind of hearing the water, kind of trickling, it's almost freeing, but also seeing it. The smell is quite refreshing, and it feels like it washes away your stresses and things." (Sophia, 16 yrs.)

3.7.5. Key differences between age groups

There were several differences between the age groups around having interactions with UGS users of different ages. Firstly, there was a difference in opinion about visiting with people of the same age.

Adolescents and older adults both spoke about using UGS as a space to meet friends, and if not visiting alone then they would normally visit with people of the same age. Interestingly, this tendency was not shared with the young adults or adult age group. It was also identified that seeing younger children in UGS was important for adolescents, adults, and older adults, but not mentioned by young adults. Adolescents, adults, and older adults all shared positive views and found it encouraging to see children being actively involved in nature:

“With the forest schools and things, it’s really important because you could teach children about how important it is, and like grow vegetables and things.” (Sophia, 16 yrs.)

A final difference that was apparent in this study was that adolescents expressed wanting separate spaces for different age groups within their local UGS, however this opinion was not shared amongst the other age groups. Finally, feeling a sense of community with all users and having community involvement in UGS was important for young adults, adults and older adults, however younger interviewees (adolescents) did not mention this. For example, Dawn spoke about a charity operating within their local UGS which aims at bringing together all members of the community:

“It’s specifically geared towards bringing together people who might not otherwise meet. Across cultures, religions, ethnicities, languages even.” (Dawn, 72 yrs.)

3.8. Discussion

Through qualitative interviews, this study took an in-depth approach to explore the properties of UGS which are important and influential for mental well-being across multiple age groups. By understanding preferences of UGS, this can help understand use of UGS which has been shown on the causal pathway to lead to health and mental well-being benefits. Overall, the findings showed that there are many common preferences across age groups about properties which can influence mental well-being in both positive and negative ways. More specifically, the study found that UGS provides a sense of escape and is a space to share with other users, but that there are practical requirements for visiting UGS, as well as important seasonal sensory components. These

can all influence how UGS can shape mental well-being. Additionally, some differences were found between age groups regarding interacting with UGS users of different ages. The two research questions proposed for this study were (1) What common properties of UGS shape mental well-being similarly across age groups?, and (2) How do UGS support social interactions across different age groups? Whilst some common themes were identified that answer research question 1, no clear commonalities were identified to answer research question 2. However, research question 2 can be answered with some key differences between age groups.

With the first research question, this can be answered with the common themes and preferences across age groups; UGS provides a sense of escape, Practical needs for visiting UGS, and Seasonal sensory components. The theme, UGS provide a sense of escape, explains how UGS can impact mental well-being through feeling less stressed and escaping the busyness of other public spaces, which is consistent with previous findings (Home et al., 2012). This preference overall is in line with the restorative environments literature in that natural spaces are a space for solace and refuge from everyday life (Ulrich, 1983). In greenspaces, individuals can avoid the overcrowding and invasion of personal space that comes with urban spaces. Additionally, this finding relates to the natural environment component of Hartig et al's., (2014) framework, in that the physical size of the space is important. Some previous research states that larger UGS are preferred over small UGS (Macintyre et al., 2019), however the findings in this study suggests that whilst this can be true, there may be more value in the spatial complexity and diversity of the space (Massoni et al., 2018). The first theme explains that an UGS which has diversity and various spaces within it, can allow for exploration, a feeling of independence and having a more personal experience with nature. This can all contribute to the feeling of escapism within an UGS. This is a helpful finding for policymakers and planners as it shows UGS users as wanting a structurally diverse space and the benefits that come from diversity within the space, and this has also been shown in other studies (Sundevall & Jansson, 2020). By applying this preference to the design of UGS, then this can lead to increased use in UGS which is an important part of the causal pathway to health benefits. The second theme that helps answer the first research question, Practical needs for visiting UGS, explains that accessibility, safety concerns, and weather dependency are all important to visitors of UGS. Referring back to the aspect of exploration described in the first theme, pathways are of importance in UGS as they allow for more movement within the space. Paved trails have also previously been

highlighted in the literature as being important facilities in parks which improve accessibility (Kaczynski & Henderson, 2008). Additionally, proximity to greenspace is an important factor for accessibility, and is associated with health-related outcomes (Fouad et al., 2023). The importance of accessibility has also been previously suggested as an important factor for adolescents and adults (Ayala-Azcárraga et al., 2019; Rivera et al., 2021). Regarding safety, perceived safety is an important aspect of UGS (Zhao & Huang, 2021) allowing restoration in these spaces (Gatersleben & Andrews, 2013). Literature shows that being in the company of others enhances restoration when there are safety concerns, but if safety is not a concern, the absence of company can enhance restoration (Staats & Hartig, 2004). Lighting is also well-documented as being an important component in relation to safety, with higher illumination being associated with higher levels of perceived safety (Zhao & Huang, 2021). Previous research with older adults has also highlighted perceived safety and the contribution of lighting in a park (Veitch et al., 2020a). Interviewees also spoke about weather dependency and its impact on visits to UGS. The preferences for dry, warm weather were not surprising, as one of the main reasons individuals visit greenspace is to enjoy the weather when it is good (warm and sunny) (Schipperijn et al., 2010). Additionally, the perspective of inclement weather as heightening the naturalness of the space aligns with previous research which describes weather as being able to invigorate the experience of nature (Bell et al., 2019).

Another theme that contributes to answering research question 1; Seasonal sensory components, explains people's diverse multi-sensory experiences and how this shapes mental well-being. Interviewees referred to multiple senses (sound, smell, sight) and how this positively impacted their mental well-being through feeling free, calm, and refreshed. This is consistent with research which has shown well-being to be impacted by multi-sensory components (Grahn & Stigsdotter, 2010; Ratcliffe, 2021; Zhang et al., 2019), and that other sensory modalities can be restorative (Ratcliffe, 2021a). In this study, it became clear that UGS users noticed and enjoyed various sensory components of UGS, and not just the visual elements. These multi-sensory components were also discussed in relation to the season and what people expect and experience in different seasons, e.g., expecting and enjoying the smell of freshly cut grass in summer. Previous research has shown that certain seasons are preferred, including autumnal and floriferous seasons (Kuper, 2018), in addition to there being an impact of greenspace on mental restoration which varies in the seasons, with greenspace positively impacting on physical activity in the summer only (Zhou et al., 2022). And, similarly to seasonal

changes, diurnal patterns and ephemeral phenomena have been found to influence the perception of urban and natural spaces (Smalley & White, 2023). Knowing the importance of multi-sensory components, it is recommended that future research includes this focus.

In terms of answering research question 2 (How do UGS support social interactions across different age groups?), the first (UGS provide a sense of escape) and third (Sharing a space with others) themes, explore both the more social aspects of visiting UGS and going to these spaces to avoid people. These findings contribute to answering research question 2, which is about interactions across different age groups in UGS. The theme 'Sharing a space with others' included varying opinions, with some people preferring to visit alone to get away from the busyness of life, whereas others described their UGS as a place to bring people together. These findings provide insight into the complex relationship between greenspace and social cohesion and adds to previous literature which suggests that physical characteristics of greenspaces intermingle with environmental perceptions and use patterns (Wan et al., 2021). In answer to research question 2, there were more differences across age groups than commonalities. Adolescents and older adults both spoke about using UGS as a space to meet friends, and if not visiting alone they would visit with those of the same age. This is consistent with previous research which describes UGS as a space for older adults to spend time socialising with others of the same age (Gaikwad & Shinde, 2019), and the general importance of other people being present in urban greenspaces (Veitch et al., 2020a, 2021). Similarly, adolescents visiting UGS with friends is a well-documented finding (Rivera et al., 2021; van Hecke et al., 2016). Additionally, adolescents, adults, and older adults all shared positive views in that they found it encouraging to see children being actively involved in nature. Although adolescents expressed wanting separate spaces for different age groups within their local UGS, this opinion was not shared with the other age groups. This is a similar finding to Sundevall & Jansson, (2020) who identified this for children, adolescents, and older adults. However, in the current study, this opinion was only expressed by adolescents. Finally, feeling a sense of community with all users and having community involvement in UGS was important for young adults, adults, and older adults, while adolescents did not discuss this. These findings build upon previous research on social cohesion as it provides the perspective of younger age groups as well as highlighting the need to explore their views more.

3.8.1. Limitations and research recommendations

Whilst a strength of this research was involving a wide range of participants including adolescents, no individuals under the age of 12 were interviewed. Going forward, research could also involve this younger age group as they are also users of UGS (e.g., using play equipment, meeting up for play groups etc.). Having their perspective, alongside their parents/guardians, would be additionally valuable as it would involve their views in the design of UGS. More generally, future research should continue to take an intergenerational approach as it has been shown that UGS users share many similar views and experiences, as well as disagreements. A community-led approach to understanding the important properties of UGS would be a more inclusive way towards understanding and designing UGS for everyone, rather than considering the views of different age groups as distinct.

More could also be learnt about social interactions. While we expected comments on social interactions to be elicited throughout the interview, questions specifically focused on this were concentrated towards the end of the interview, perhaps resulting in participants giving less rich comments on this topic given the length of the interview and potential fatigue. Research could also explore interactions between age groups, as well as views of non-users of UGS. Exploring reasons for not visiting these spaces could highlight what properties are not beneficial for mental well-being or a reason for avoiding UGS. The interviewees in the current study did express some negative opinions, such as safety concerns they had when visiting UGS, but overall, there was very little discussion about conflicts or intergenerational tension in urban greenspaces. Although a specific question about conflicts was not asked, it is surprising that the topic did not emerge due to previous literature having noted interpersonal conflicts (Groshong et al., 2020; Mak & Jim, 2018; Seaman et al., 2010). This may have been a result of the interviewees being regular visitors of urban greenspaces and holding mostly positive views of the spaces they visit. By interviewing individuals that avoid UGS altogether, future research may provide some more insight which could inform how UGS are designed and what properties that need prioritising in order to be beneficial for mental well-being. Additionally, the representation of views from underserved and marginalised populations was lacking in this research; previous research has uncovered the distinct and varied ways in which, for example, disability groups (Bell & Foley, 2021) and low-income minority ethnic groups (Cronin-de-Chavez et al., 2019) perceive the benefits of UGS and consideration of these views is vital

to addressing inequalities in access and use of UGS as well as in designing truly inclusive UGS.

A final limitation of this study would be that participants' opinions may have been impacted by the recent COVID-19 pandemic and how public space is utilized (Lemyre & Messina, 2023). How participants use and perceive the potential benefits of UGS may have changed since the pandemic (Stock et al., 2022). Enthusiasm in the post-pandemic period may have led to more positive than expected opinions in the interview. Despite limitations, there were several strengths to the current study. Firstly, this study was able to identify common opinions across multiple age groups, as well as some key differences, and hence provide an intergenerational lens to the research topic. This provides valuable insight into how spaces are used as a collective, rather than for a sole user in mind. This study was able to capture the insights into the properties of UGS which influence the mental well-being of UGS users. Conducting qualitative interviews allowed for in-depth discussion around the reasons why certain properties were more or less influential for mental well-being and social interactions than others, rather than simply listing physical components that users liked or disliked.

3.9. Conclusion

The current study focused on the properties of UGS which shape mental well-being across generations. It was found that there are mostly similar opinions across age groups regarding such properties, bar some distinct preferences from adolescents who may prefer spaces within UGS specifically designed for them. Overall, users of UGS explained that these spaces provide a sense of escape, there are practical needs for visiting, there is importance around sharing UGS with other users, and there is recognition of seasonal sensory components in the space. Whilst this is encouraging and shows that UGS are catering for a wide range of ages, this study is a starting point for future research which takes intergenerational approaches to exploring UGS use by multiple marginalised communities as well as the views of non-users. By confirming these findings, it could influence how UGS are redesigned in a community-led way, and therefore improve social cohesion between generations and the overall mental well-being of local residents. The findings of the current study are helpful for local neighbourhood landscape planners and designers as it will enable UGS to be designed to be beneficial for all generations within society and align with aims of current policies, e.g., age-friendly, child-friendly cities. Policy recommendations include involving members of the community, of different ages,

in the design of UGS, as well as encouraging community members to use their UGS which can then lead to health benefits. For example, policymakers and landscape planners could hold meetings with community members to gather their perspective and enable their views to be heard. By actively engaging the community in the design of a space, as well as encouraging all groups within the community to use the space, it would allow for a sense of ownership which could lead to increased visitation and maintenance of the space, and therefore have a positive impact on mental well-being.

Note: In preparation for this thesis, additional content from the publication which were required for the journal format can be found in [Appendix 7](#). This includes sub-sections for details of funding sources, ethics statement, authorship statement, declaration of competing interest, acknowledgements, and any supplementary materials.

3.10. Contribution to thesis

This chapter presented the first empirical study in this thesis and addresses thesis research question 1, 'What multi-sensory properties of urban greenspaces are beneficial for mental well-being for different age groups, and what are the commonalities across generations?'. This study first recognised the current state of knowledge in the field which showed, through a literature review, that UGS can provide mental well-being benefits for all ages but so far studies tend to only focus on one age group at time. There is a lack of studies which have taken a deep exploratory look at the properties of UGS which can be beneficial across generations, and the study presented in this chapter aimed to address this gap.

This study led to the creation and interpretation of new knowledge through an original qualitative study which was subsequently peer-reviewed and published. This study demonstrated that there are many commonalities across age groups regarding the properties of UGS which are important for mental well-being, identifying four key themes. By using a qualitative interviewing method, this study was able to show a deep and rich insight with the data collected. Few studies to date have researched with multiple age groups and looked at similarities between them, therefore this study has taken a novel approach and contributed new knowledge to the field.

This chapter has also demonstrated my ability to conceptualise, design and implement a project as well as recognise challenges which required adjustment to the project design. Firstly, by involving multiple age groups, this study faced time challenges in relation to designing interview questions and recruitment strategies for multiple ages. Extra time

was needed to pilot the proposed interview questions with adolescents to make sure the language used in the questions was understandable. Whilst the initial questions did not change after piloting, I learnt that this was an essential step when conducting interviews with different age groups. As well as designing the interview questions, I also learnt about the importance of tailoring recruitment strategies for different age groups. With the two subsequent pilot studies in this thesis, participants were all students recruited solely through advertisement around the university. For this qualitative study which had a wider age range, this strategy was not appropriate. Instead, local organisations (e.g., Young People's Advisory Group, Bristol Old People's Forum (BOPF)) were approached and the study was advertised through their community. Whilst successful in reaching the target sample size, this meant communicating with and managing multiple organisations simultaneously which took time. Furthermore, reflecting on the recruitment strategies adopted in this study, (and in common with all the empirical studies included in this thesis), a key limitation is selection bias and that participants represented in the sample are often those who want to take part in research and are more likely to respond to research adverts (Šimundić, 2013). With this qualitative study, adolescents were members of an advisory group who regularly take part in research. The older adults in the sample were regular members of the BOPF community and involved in activities of this organisation.

Moreover, from conducting this study I have learnt the benefits of using specialist software to aid in qualitative data analysis. I used NVivo to upload the interview transcripts, code, and categorise my data based on age groups. The software was also used to organise codes and easily extract quotes which were representative for each code and theme, and which were common across all the age groups. From learning NVivo and understanding its efficiency with data analysis, this software is taken forward and utilised in the analysis of the qualitative data in the final experiment in this thesis (Chapter 6).

Lessons were also learnt in relation to ethical considerations. In order to understand the properties of UGS which are beneficial for mental well-being across the lifecourse, participants were recruited across multiple ages which included from vulnerable groups (adolescents under 18 years old and older adults over 65 years old). This required additional ethical consideration, for example, for participants under 18 years old, consent from a parent or guardian was also needed to allow for participation. Whilst this made the ethical approval process longer, it meant that I could reach a wider range of

participants and involve younger people in the research which is essential as they are also users of UGS. Having only had experience with recruiting adults for research, I learnt from this study what ethical considerations need to be made when recruiting from other age groups. Additionally, building a rapport with adolescent participants was often more difficult than participants from the other age groups, and highlighted the importance of building a good rapport with participants. The majority of these younger participants were shyer and more withdrawn in their communication and more prompts and follow-up questions were needed in order for thoughts to be expanded on and provide more detail. After this was implemented as well as patience and time provided for participants so they could familiarise themselves with the interview environment, interview responses were similar in length and detail to participants of other age groups.

A critical understanding of the methodology of enquiry is also demonstrated here. The results in this study would have not been possible if a quantitative methodology had been developed. The qualitative interviews allowed for a holistic approach to be taken and explore the subjective experience of people visiting UGS, explaining how they can benefit their mental well-being and what properties can impact that. Participants in the study were able to provide their own opinions and perspectives and talk in detail about their experiences in UGS. By conducting a qualitative study, a broad and in-depth investigation could be taken. In contrast, a quantitative study would not have been able to achieve this level of depth and detail (Taherdoost, 2022). Quantitative studies, such as experimental studies, have their own advantages such as creating a controlled and replicable environment. But by using a quantitative method such as a survey, it may have oversimplified responses and experiences and lacked the flexibility to explore concepts and details which participants discussed naturally in the moment.

For this study, a semi-structured interview methodology was chosen due to its flexibility. However, alternative methodologies could have brought about different findings. For example, the life grid method for qualitative research could have provided more detail about the lifecourse of individual participants as it allows individuals to reflect on different periods of their life (Lalanda Nico, 2016). This may have shown how individuals have felt about UGS depending on when they were different ages and in different stages of their lives. However, this method is time extensive and relies heavily on the memory recall ability of individuals. Focus groups for the different age groups could have also been a possible method of enquiry. Whilst focus groups are useful in allowing participants to share their experiences with a group which may promote discussion, this may have been

uncomfortable for participants when openly discussing mental well-being and the presence of other people may lead to socially desired answers (Acocella, 2012). In contrast with more individual approaches such as interviews, other methods involving big data such as text mining and analysing social media posts could provide a broader insight into the properties which shape preferences for UGS (Sim & Miller, 2019; Wang et al., 2021; Xu et al., 2019). This approach could yield a larger sample and represent more opinions, however, could also lack depth and detail in the data analysed. Additionally, go-along interviews may have also been beneficial, particularly with the adolescent participants. Adolescents being in an UGS which is familiar to them and where they would usually visit may allow this age group to open up more with their responses, as they may feel more comfortable and at ease being in a familiar space. These have been used previously and been effective as they put emphasis on the place rather than the person (Bell & Bush, 2021; Finlay & Bowman, 2017).

Whilst some strengths and weaknesses have already been recognised in the published paper, I reflect more here on the wider strengths and weaknesses of this study. For this study, I carried out semi-structured interviews with participants which I learnt to be a strong method. The method was flexible and allowed me to gather rich data which might not have been possible with a more rigid approach. I was able to adapt the discussion depending on what participants spoke about. For example, some participants naturally spoke about topics which I was going to ask about and this adjusted the order of my questions as well as what prompts and additional questions I asked. Through conducting this study, I reflected on myself as a researcher and the bias which I bring to the topic and how I managed this during qualitative data collection. During the interviews, it was challenging to remain objective and not express my positive opinions towards UGS, however I did recognise this as a potential challenge before commencing. To remain objective, I made sure to construct open-ended interview questions which lack a direction or bias. I also regularly checked in with myself after each interview to make sure I had not influenced the conversation or interpretation. Whilst I implemented strategies to mitigate bias, my bias as a researcher who has a positive outlook towards UGS and their benefits may have influenced my data and analysis.

Moreover, the participants recruited in this study were all local to Bristol. Whilst qualitative research does not aim to be generalisable, it is important to recognise that the data and themes generated in this study are in relation to UGS in Bristol. The themes may have been different for people living in other areas of the UK, as well as in urban

areas outside of the UK. If I had recruited participants from a city with fewer greenspaces compared to Bristol (a fairly green city (Millets, 2024)), different responses may have been recorded. Additionally, the type of UGS which participants could talk about was kept quite broad which resulted in numerous types of UGS being described, e.g., parks, fields, woodlands, cycle paths. The study could have instead focused on one specific type of UGS and therefore made the results more specific, resulting in more distinct applications for policy. Furthermore, due to the risk of transmission of Covid-19 at the time, the interviews were conducted online using Zoom rather than face-to-face. This was a necessary step in order to keep participants and the researcher safe, and there has also been research published supporting the use of virtual interviews and benefits which include reduced costs, a comfortable setting, and inclusivity (Olliffe et al., 2021). However, it could have been easier to build rapport with participants and have a more natural conversation if they had been conducted face-to-face.

Of the themes identified in this study, there was scope in this thesis to take forward one topic to inform the main focus of an experimental study (Chapter 6). To decide this, firstly a mind map was created in order to deliberate the different possibilities for each theme and how they could lead onto an experimental study (for mind map, see [Appendix 8](#)). This was also informed through scoping literature searches in the literature on the four themes. A clear gap was identified regarding the social aspects of UGS. Few studies have investigated the impact of other people being present in UGS and this was an important factor in the present qualitative study. The theme, 'UGS being a space to share with other users' and the findings in relation to crowding in UGS and being in a space where you can get away from people (spaces needing to be big enough to be able to escape), were chosen to be taken forward.

The next chapter presents the first of two pilot studies which are included as published papers. These pilot studies inform the methods adopted in the final experimental study of this thesis (Chapter 6). Whereas this study has helped to inform a narrower topic of interest for the final experimental study. The next three chapters (4,5,6) include experimental studies but have all included a qualitative aspect due to the depth and detail which this approach can bring to the research.

Chapter 4: Pilot study 1

Title

Exposure to green and historic urban environments and mental well-being: Results from EEG and psychometric outcome measures

Reference

Reece, R., Bornioli, A., Bray, I., and Alford, C. (2022). Exposure to Green and Historic Urban Environments and Mental Well-Being: Results from EEG and Psychometric Outcome Measures. *International Journal of Environmental Research and Public Health*. 19, 13052.

4.1. My contribution

The work in this chapter has been published in a peer-reviewed journal; the *International Journal of Environmental Research and Public Health (IJERPH)*. This study was internally QR funded by the Faculty of Health and Applied Sciences at The University of the West of England (UWE), Bristol, UK, and supported by the Economic and Social Research Council (ESRC) as part of my studentship with the South West Doctoral Training Partnership (SWDTP). An acknowledgement for this study being included in this PhD thesis is stated in the original publication and all authors gave permission for this research to be included in this thesis. As lead author, I contributed to determining the methodology of the study, whilst also being responsible for conducting a literature review, data curation, formal data analysis, writing the original paper draft, as well as reviewing and editing the paper. This was supported by Dr Issy Bray, Dr Chris Alford, and Dr Anna Bornioli, who were responsible for the initial conceptualization of the study, aiding in the study methodology, formal analysis, reviewing and editing.

4.2. Overview

This chapter continues the focus on UGS and mental well-being and pilots several aspects which are essential for research in this area. Indirectly, it provides an initial stage in answering thesis research question 2, 'Is virtual reality (VR) a feasible and acceptable tool for researching the multi-sensory benefits of urban greenspaces for mental well-being?'. This study used a simpler virtual exposure by only using flat-screen. The main aim of this first pilot study presented in this chapter was to test the concurrent validity of psychological and physiological measures of mental well-being. This study tested the feasibility, acceptability, and practicality of a long experimental set-up (1.5 hours) which included both psychological (mood using the UWIST MACL (Matthews et al., 1990)) and physiological (EEG) measures of mental well-being. Secondly, this study adopted a factorial design which explored the effects on outcome measures when non-natural elements are added to natural scenes. In experimental environmental psychology, research focuses extensively on pristine natural environments which have little influence from human or non-natural elements. Less is understood about non-natural elements (e.g., buildings) of greenspaces and the effect on mental well-being outcomes. So, this study explored built historic elements, as a non-natural element present in greenspaces, and how this can affect psychophysiological outcomes.

This experimental study presents two key contributions to the literature. The findings revealed divergent patterns between psychological and physiological measures of wellbeing and found that non-natural elements can confer psychological benefits to a similar or even greater extent than natural ones. These findings inform methodological choices made in Chapter 6 with regards to the selection of measures and stimuli. Complementary psychological and physiological measures are used in Chapter 6 and the presence and quantity of people in urban greenspaces is chosen as a non-natural element to investigate which could confer benefits or detriments to well-being.

Further methodological detail for this published paper are presented in [Appendix 9](#).

4.3. Chapter 4 research questions

RQ1: Does exposure to urban environments with green and historic elements, and their combination, benefit mental well-being?

RQ2: Do psychometric and physiological measurements agree when assessing the mental well-being benefits of exposure to different urban environments?

4.4. Abstract

Previous studies have identified the benefits of exposure to green or historic environments using qualitative methods and psychometric measures, but studies using a combination of measures are lacking. This study builds on current literature by focusing specifically on green and historic urban environments and using both psychological and physiological measures to investigate the impact of virtual exposure on mental well-being. Results from the psychological measures showed that the presence of historic elements was associated with a significantly stronger recuperation of hedonic tone ($p = 0.01$) and reduction in stress ($p = 0.04$). However, the presence of greenness had no significant effect on hedonic tone or stress. In contrast, physiological measures (EEG) showed significantly lower levels of alpha activity ($p < 0.001$) in occipital regions of the brain when participants viewed green environments, reflecting increased engagement and visual attention. In conclusion, this study has added to the literature by showing the impact that historic environments can have on mental well-being, as well as highlighting a lack of concordance between psychological and physiological measures. This supports the use of a combination of subjective and direct objective measures in future research in this field.

Keywords: green environments; historic environments; well-being; EEG; virtual exposure; restorative environments

4.5. Introduction

It is vital to understand how exposure to different environments can impact mental well-being. Globally, citizens have poor mental health with around 5% of adults suffering from depression (World Health Organization, 2023b) and in the UK, 74% of people suffer from high levels of stress (Mental Health Foundation, 2018). Despite the benefits of living in urban settings, including increased work and social opportunities and access to services, research has found that living in an urbanised area can have a negative impact on mental health (Lecic-Tosevski, 2019; Peen et al., 2010; Ventriglio et al., 2021), and can be a risk factor for mental health conditions, including major depression and schizophrenia (Adli, 2011). This is a public health concern, given that 55% of the global population lives in urban settings (World Health Organization, 2022c).

On the other hand, the mental well-being-benefits of spending time in nature are well known. Importantly, according to the literature, exposure to urban green infrastructure can be beneficial for the health and well-being of urban populations (McKinney &

VerBerkmoes, 2020; Tzoulas et al., 2007; van den Berg et al., 2015). These benefits include stress reduction (Ward Thompson et al., 2012), positive self-reported well-being (Navarrete-Hernandez & Laffan, 2019), improved cognitive function (Suppakittpaisarn et al., 2017) and more. Therefore, there is growing consensus on the notion that incorporating natural elements in cities can be a successful strategy to improve mental well-being at the population level.

Further, exposure to certain environments through virtual methods has also been found to be beneficial for mental well-being (Reece, Bornioli, Bray, Newbutt, et al., 2022; Subiza-Pérez et al., 2017, 2021) and can lead to restorative benefits (Gao et al., 2019; Hedblom et al., 2019; White et al., 2018). Viewing environments virtually can be beneficial for populations with limited mobility and access to real environments (e.g., older people, prisoners) or in clinical settings, and it is also an important tool in researching the benefits of exposure to different environments (Bell et al., 2020; Ünal et al., 2022).

From a theoretical point of view, benefits from natural environments have been explained by several psychological theories (Kaplan & Kaplan, 1989; Ulrich, 1981). Attention Restoration Theory (ART) explains exposure to natural environments as being a restorative experience, allowing for the recovery of directed attention and mental restoration (Kaplan & Kaplan, 1989). Natural environments allow for attention to be captured in a 'softly' fascinating way but do not deplete attentional resources (Berto, 2005). Further, Stress Recovery Theory (SRT) states that exposure to natural environments can allow for recovery from stressful situations (Ulrich, 1981).

Some studies have shown that built settings without the presence of traffic, and with no nature, can also be restorative and support mental well-being. These include squares (Subiza-Pérez et al., 2020), streets (Bornioli et al., 2018a; Gidlow et al., 2016; Karmanov & Hamel, 2008), open built spaces (Fornara, 2011), and museums (Kaplan et al., 1993; Mastandrea et al., 2019). From a theoretical perspective, these benefits can also be explained by ART. According to ART, any environment which presents the restorative properties of being away, fascination, compatibility and extent can offer restorative benefits (Kaplan & Kaplan, 1989). Historic environments have emerged as a specific typology of built places which have a high restorative potential (Bornioli & Subiza-Pérez, 2022; Weber & Trojan, 2018). Numerous studies have suggested that historic places, including houses of worship (Herzog et al., 2010; Ouellette et al., 2005), museums (Kaplan et al., 1993; Mastandrea et al., 2019) and historic urban spaces (Fornara, 2011) can support mental well-being and restoration.

According to the evidence, these potential benefits from exposure to historic environments are due to two types of characteristics. First, the objective characteristics of historic buildings, including the geometry, can contribute to restoration (Buras, 2020), with nature known to encompass a rich fractal content (bottom-up characteristics include objects' shapes, sizes, and luminance) which can lead to 'effortless looking', as explained by ART (Kaplan & Kaplan, 1989) and reduce stress (Brielmann et al., 2022). This fractal fluency, and 'effortless looking' can occur in built and historic environments, as well as natural environments (Brielmann et al., 2022), and it is the fractal elements which are used to design architecture in the first place (Buras, 2020). Second, subjective, top-down features might also explain the mental well-being benefits of exposure to historic settings. Perceptions, associations and memories related to cultural identity and spirituality triggered by historic buildings can support restorative experiences and positive affective outcomes (Eriksson & Wiklund-Gustin, 2014; Ouellette et al., 2005; Packer & Bond, 2010). Exposure to environments which present both natural and historic elements might be especially beneficial for mental well-being, as green and historic environments might be, at the same time, quiet and interesting. In line with this idea, previous research found mental well-being benefits in historic cemeteries (Nordh et al., 2017), a rural monastery (Ouellette et al., 2005), and a cathedral courtyard (Bornioli et al., 2018a).

Previous studies attesting to the mental well-being benefits of exposure to historic settings employ qualitative methods (Bornioli et al., 2018b; Nordh et al., 2017), psychometrics (Bornioli et al., 2018a), and surveys and perceptual scales (Fornara, 2011). However, there is a lack of studies examining physiological measures and/or a combination of psychometric and physiological measurements. Physiological outcomes have the advantage of providing an objective and precise measure of participants' responses, which are not subject to participant bias in expression. Such measures include not only traditional physiological variables, such as skin conductance and heart rate but also electroencephalogram (EEG). The latter allows for the recording of brain activity and can detect stress and arousal (Bagheri & Power, 2020; Huang et al., 1996). In addition, the combination of physiological and psychometric measures can provide a more complete picture and allow for the assessment of the extent to which they are aligned, and also if questionnaires provide concordant measures of participants' mental well-being. In a previous study, we used a combination of physiological and psychological measures to assess mental well-being when participants were exposed to natural green and blue environments, and a built historic environment (Reece, Bornioli, Bray, Newbutt, et al., 2022). In this experiment, we found that all three environments were associated

with mental well-being benefits, although there was no clear concordance between the physiological and psychological measures in terms of which was the most effective at improving mental well-being. This study showed the importance and relevance of looking at both subjective and objective outcomes, as they can provide different results which can influence recommendations made in the field of research.

In contrast, the current study assessed the impact of exposure to four urban settings with varying levels of green and historic elements, all protected from motor traffic, on mental well-being, also combining psychometric and physiological measurements. The first aim was to assess whether exposure to urban environments with green and historic elements and their combination, supported mental well-being. The second aim related to the agreement between the outcome measures used. The research questions posed for this study were:

RQ1: Does exposure to urban environments with green and historic elements, and their combination, benefit mental well-being?

RQ2: Do psychometric and physiological measurements agree when assessing the mental well-being benefits of exposure to different urban environments?

4.6. Methods

4.6.1. Participants

35 healthy undergraduate psychology students with normal or corrected-to-normal vision were recruited from within a UK university via the psychology participant pool between October 2019 and January 2020. Most participants were female (Table 4.1). Participants who signed up for the study were screened for exclusion criteria. Due to the use of electrodes on the skin for measuring EEG, participants were excluded if they suffered from a skin allergy or hypersensitive skin, had experienced an epileptic seizure within the past 12 months, had current or previous hypertension, anxiety, psychiatric, neurological disorders, or current illness (e.g., Influenza), and/or were taking prescribed medication for brain or psychiatric conditions (e.g., anxiety, depression, or epilepsy).

	Median	Range	Percentage of sample
Age (yrs)	20.0	24.0	
Male			16.7
Female			83.3
Black and Minority Ethnic			6.6

Table 4.1. Participants' sociodemographic characteristics.

Five participants were excluded from the EEG analysis because of failed EEG recordings, leaving a total sample of 30 datasets for EEG analysis. All participants enrolled in the study voluntarily and gave their informed consent before they participated in the study. Participants received course credits in exchange for their participation.

4.6.2. Stimuli

Based on the first aim of the study to assess the mental well-being potential of exposure to urban green and historic settings, a 2×2 factorial design was chosen, with the factors being greenness (green, non-green) and architectural style (historic, modern). The four conditions, green modern, green historic, non-green modern, and non-green historic, are described in Table 4.2. This design allowed us to estimate the effect of each characteristic (greenness and architectural style) on mental well-being variables. At the same time, the design also allowed us to test for an interaction between green and historic environments.

	Green	Non-green
Historic	Green historic (A)	Non-green historic (B)
Modern	Green modern (C)	Non-green modern (D)

Table 4.2. 2 x 2 Factorial design (four conditions).

Four videos depicting urban traffic-free scenes, one per condition, were created for the experiment (Figure 4.1). Videos were filmed on several afternoons in July 2019. Weather conditions were dry and mostly sunny across all the videos. Each video lasted 4 min, and each included several 30 s sequences of environments in Bristol, UK. The videos in the green conditions (green modern and green historic) depicted built settings (rather than parks) with green elements such as trees, bushes, and grass. The videos in the non-green

conditions (non-green modern and non-green historic) depicted built settings of modern styles including glass and metal materials and smooth concrete surfaces. The videos in the historic conditions depicted built historic settings, including 18th-century structures, cobbled-stone pavements, and religious and historic elements (lamp posts, statues). Videos showed a low to a moderate number of people (e.g., 20 pedestrians per minute). These were projected on a 20" flat-screen computer monitor. Each video was preceded by a short video (2 min) of a motorway road with heavy traffic acting as a stressor (Figure 4.2). The order of the experimental videos was randomized.

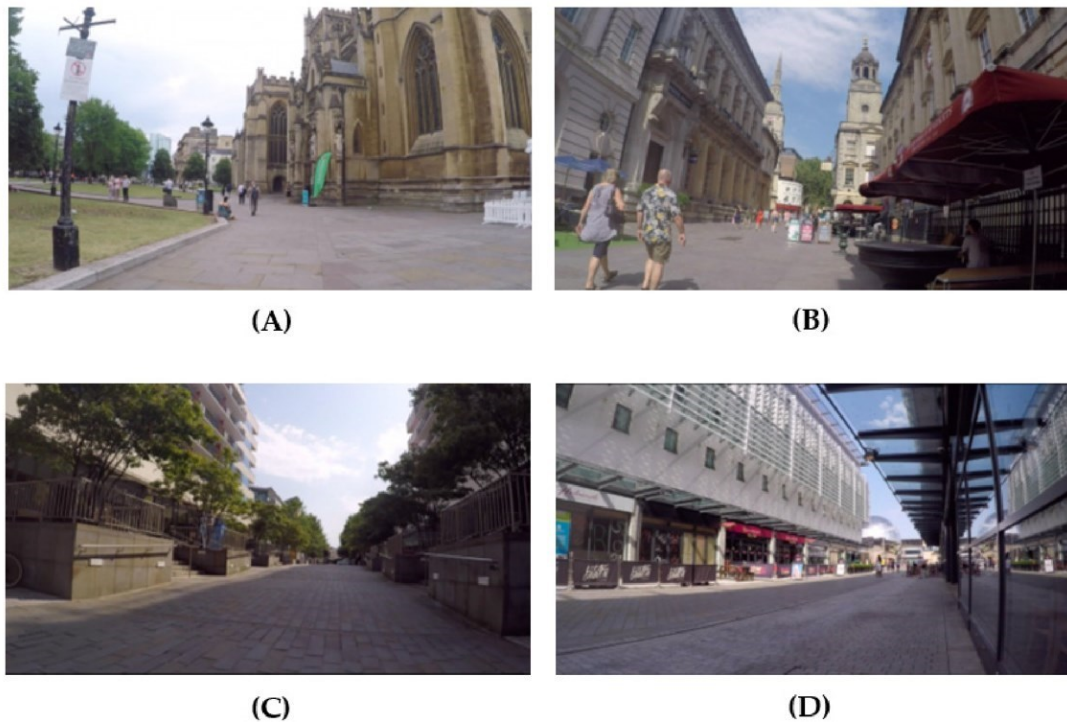


Figure 4.1. Visual stimuli for environment conditions: (A) green historic; (B) non-green historic; (C) green modern; (D) non-green modern.



Figure 4.2. Visual stimuli for the traffic (stressor) condition.

4.6.3. Design

A within-subject cross-over 2×2 factorial design was employed, where participants served as their own control. Figure 4.3 provides an overview of the experimental procedure. Participants began by watching a 4-min video of the stressor, followed by baseline completion of the affect scale (Section 0). This was followed by four sections—one per condition—in which participants watched 4 min of the video condition and completed the affect scale to measure self-reported psychological outcomes ([Appendix 13](#)). Each section terminated with a shorter stressor video (2 min) that aimed to bring participants back to a negative mood, except for Section 4 which concluded with a final questionnaire (the affect scale). Participants were randomly assigned to the order of viewing the sections, but all participants watched all videos. Physiological measures (EEG) were recorded continuously throughout the experiment. The experiment was piloted with two participants, which confirmed that no changes were needed to the length of the videos or the general procedure.

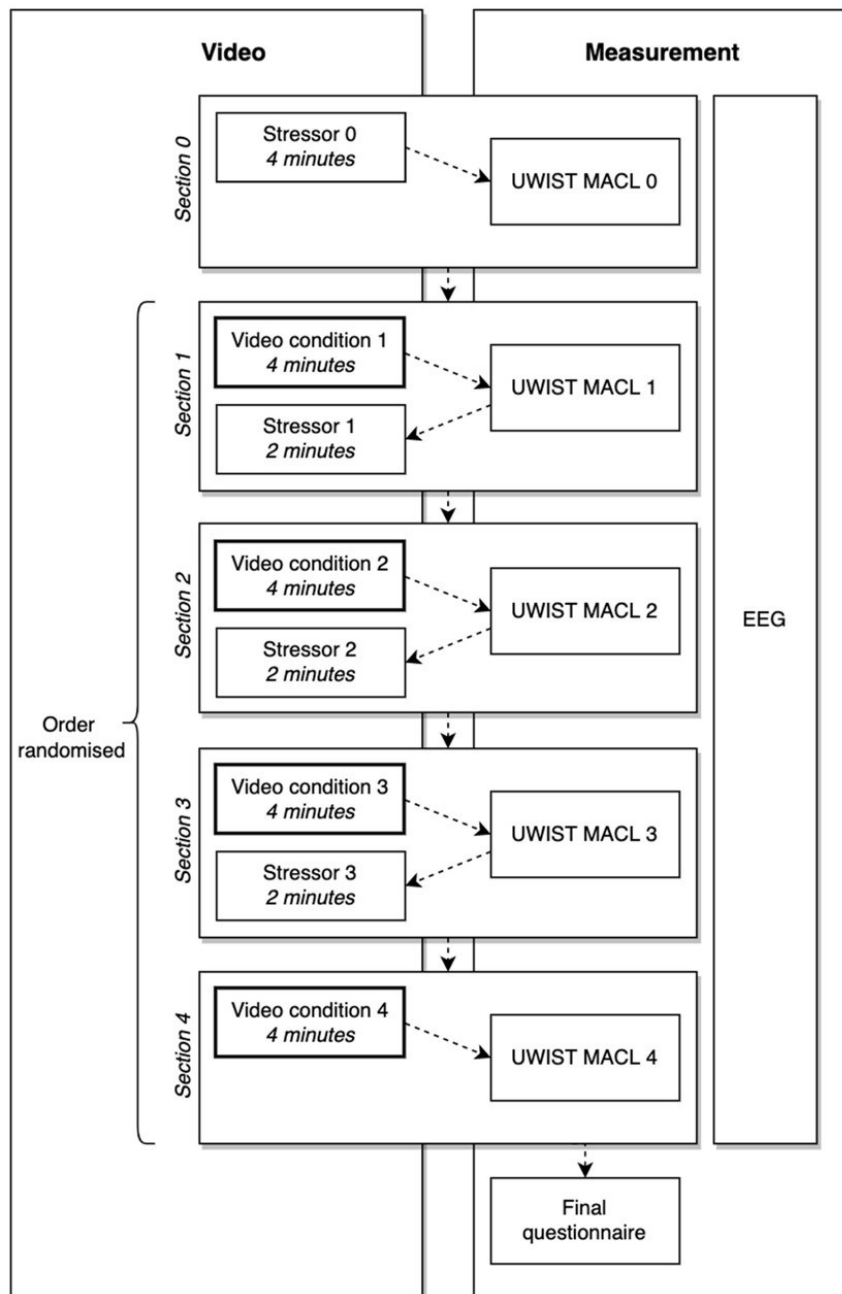


Figure 4.3. Experiment procedure.

4.6.4. Measures

4.6.4.1. Subjective measure

Mood was subjectively measured using the shortened version of the University of Wales Institute of Technology Mood Adjective Check List (UWIST MACL) (Matthews et al., 1990). This scale includes four items (relaxed, nervous, happy, sad). All items are measured on a 4 point scale. A score for hedonic tone and stress is produced from this measure, ranging from a minimum of 2 to a maximum of 8. Following Matthews et al., (1990), scores for happy and reversed scores for sad were combined to calculate a score

for hedonic tone. Scores for nervous and reversed scores for relaxed were combined to calculate a score for stress. The scale was completed on Qualtrics (Qualtrics, Provo, UT, USA, 2022) after viewing each video.

4.6.4.2. Objective measure

EEG was measured continuously during the experiment as an objective measure of brain activity and relaxation. EEG is a reliable measure for detecting changes in brain activity during relaxing and stressful conditions (Saidatul et al., 2011). Measurements were recorded using a non-invasive cap with 32 electrodes, and electrode gel which was used to ensure low impedances. The electrode channels were connected to a QuickAmp amplifier. BrainVision Recorder 2 (BrainVision Recorder, Vers. 1.23.0001, Brain Products GmbH, Gilching, Germany) was used to record the data. A sampling rate of 1000 Hz and a notch filter of 50 Hz was applied. Markers on the recording identified when traffic and environment stimuli started and finished.

BrainVision Analyzer 2 (BrainVision Analyzer, Version 2.2.0, Brain Products GmbH, Gilching, Germany) was used to analyse the data. The EEG dataset was filtered with a low cutoff at 0.1 Hz and a high cutoff at 100 Hz. For electrodes with high impedances, pooling was conducted to create a new averaged channel. The data were then segmented into sections for traffic and environment. These sections were further segmented into 10 s sections. After segmentation, the data was examined for physical artefacts (e.g., muscle movement) using a semi-automatic inspection. Segments were removed if too many artefacts were present. Eye movements (blinks) were also removed using ocular correction with independent component analysis. Next, the data were re-referenced to the common average reference, and the sampling rate was changed to 512 Hz. Segmentation was conducted again to divide the data into 2 s segments. The data was transformed from the time domain to the frequency domain using the Fast Fourier Transform (FFT).

Spectral power (μV^2) was exported for theta (4–7 Hz), alpha (8–12 Hz), and beta (13–30 Hz) frequency bands and transferred into an Excel spreadsheet. The overall frontal activity was averaged for electrodes Fp1, Fp2, Fz, F3, F4, F7, and F8. The medial frontal activity was averaged over electrodes F3 and F4. The lateral frontal activity was averaged over electrodes F7 and F8. The left frontal activity was averaged over electrodes F3 and F7. The right frontal activity was averaged over electrodes F4 and F8. Finally, overall occipital activity was averaged over electrodes O1, Oz, and O2.

4.6.4.3. Additional measures

Further measures included a final questionnaire on familiarity with the environments, landscape preferences for green versus urban and modern versus historic styles, and preference for contemplation of environments, which were all measured on 5-point scales. For each environment, three words could be chosen which the participants best thought described the environment shown. This served to check that participants were perceiving the environments as intended. The choice of descriptors included: green, urban, historic, natural, old, modern, new, attractive, cultural, and built. Additionally, sociodemographic data were collected for age (in whole years), sex (female, male, other, prefer not to say), and ethnicity (17 listed options to choose from) ([Appendix 13](#)).

4.6.5. Procedure

Ethical approval was provided by the Faculty Research Ethics Committee (FREC) from The University of the West of England and was in accordance with the Declaration of Helsinki ([Appendix 10](#)). A full risk assessment was completed and approved before the study began. Upon arrival in the lab, participants were asked to read a participant information sheet ([Appendix 12](#)) and sign an informed consent form before taking part in the study ([Appendix 11](#)). Then, the EEG equipment was set up. Participants were seated 46 cm away from a flatscreen Hewlett–Packard computer monitor (57 × 34 cm) with a loud speaker and asked to imagine themselves in the environments that were to be shown in the videos. Participants were then shown the video sequences presented in Figure 4.1 while EEG measurements were recorded, completed the UWIST MACL scale after each video sequence, and then completed the final questionnaire. Finally, the participant was thanked and debriefed. The total duration of the experiment, including setup, testing, and wrapping up, was around 1.5 h for each participant.

4.6.6. Data analysis

Data were analysed using IBM SPSS Version 26 (IBM Corp., Armonk, NY, USA) and Stata 17 (Stata Corp, College Station, TX, USA). Subjective measures were analysed with linear mixed-effects models using a long-format dataset. Objective (EEG) data were analysed using repeated measures multivariate analysis of variance (MANOVA) as well as analysis of variance (ANOVA) to analyse separate variables. Due to the EEG data not being normally distributed, the log values were used in analyses. Analyses were also Bonferroni-adjusted. All analyses used two-tailed significance levels ($p < 0.05$).

4.7. Results

4.7.1. Descriptive statistics

4.7.1.1. Subjective measures

Tables 4.3 and 4.4 show the mean levels of hedonic tone and stress for the stressor (traffic) condition and the four experimental conditions. Higher scores indicate improved hedonic tone (Table 4.3) and greater perceived stress (Table 4.4). These descriptive statistics show that mean levels of hedonic tone were higher when viewing the four environment videos compared with the traffic video, and stress levels were lower.

	Green	Non-green
Historic	6.91 (0.93)	7.00 (0.92)
Modern	6.68 (0.68)	6.70 (1.31)
Traffic	5.88 (1.09)	

Table 4.3. Mean scores (SD) for hedonic tone in environment videos.

	Green	Non-green
Historic	2.62 (0.65)	2.62 (0.65)
Modern	2.82 (0.76)	2.85 (1.02)
Traffic	4.53 (1.33)	

Table 4.4. Mean scores (SD) for stress in environment videos.

4.7.1.2. Additional measures

Participants also reported their general preference for environments. Regarding preference for green or urban environments, most participants preferred green environments ($n = 19$), some participants had more of a preference for urban areas ($n = 7$), and four participants indicated no preference. When asked to indicate a preference for modern or historic environments, the majority of participants preferred historic environments ($n = 13$), some preferred modern environments ($n = 10$), and seven participants had no preference.

For each video shown, participants were required to choose a maximum of three words from a list that they would use to describe the environment shown. For the green historic

environment, the three most popular descriptors chosen were ‘historic’, ‘attractive’, and ‘old’. The same three descriptors were also the most popular choices for describing the nongreen historic environment. For the green modern environment, the three most popular descriptors chosen were, ‘urban’, ‘built’, and ‘green’. Finally, for the non-green modern environment, the popular descriptors were, ‘modern’, ‘built’, ‘urban’, and ‘new’ (‘urban’ and ‘new’ had the same number of responses).

At the end of the experiment, participants reported their familiarity with each of the four environments that had been shown. Responses showed that participants were least familiar with the green modern environment and most familiar with the green historic environment, as shown in Table 4.5.

	Green	Non-green
Historic	3.97 (1.17)	3.91 (1.26)
Modern	2.32 (1.36)	3.82 (1.27)

Table 4.5. Participants' familiarity with the visual stimuli, M(SD). 5 = 'I am very familiar', 1 = 'I am not familiar at all'.

Regarding appreciation of environments, most participants ($n = 20$) stated they would ‘sometimes’ spend time in environments just to appreciate them. Six participants stated they would ‘often’ spend time, one participant said they would ‘very often’ spend time in environments just to appreciate them, two participants were not sure, and one participant did not respond.

4.7.2. Linear mixed-effects models

4.7.2.1. Subjective measures

General Linear Mixed Models were used to estimate the effects of exposure to green and historic urban environments and any interactions between these. In these analyses, green, historic, age and sex were treated as fixed effects, thereby controlling for age and sex. The results of the final models are presented in Table 4.6 (hedonic tone) and Table 4.7 (stress).

Variables	Coefficient	Std. Err.	z	$p < z $	95% Conf. Interval	
Green	-0.09	0.12	-0.77	0.44	-0.32	0.14
Historic	0.03	0.12	2.58	0.01	0.07	0.53
Sex	-0.33	0.31	-1.07	0.28	-0.94	0.27
Age	-0.46	0.21	-2.17	0.03	-0.09	-0.00
Constant	8.40	0.88	9.56	0.00	6.68	10.13
Observations	132					
Number of groups	33					
LR test vs. linear model: $\chi^2(01)$	30.61					
Log likelihood	-159.37					
Wald $\chi^2(4)$	12.00					
Prob > χ^2	0.02					

Table 4.6. Hedonic tone (Information Criterion 361).

We found no evidence that exposure to green environments significantly improved hedonic tone or decreased stress. There is some evidence that exposure to historic environments increased hedonic tone ($p = 0.01$) and reduced stress ($p = 0.04$). There was no evidence of an interaction between green and historic, so this term was removed from the final models.

Variables	Coefficient	Std. Err.	z	$p < z $	95% Conf. Interval	
Green	0.00	0.12	-0.00	1.00	-0.23	0.23
Historic	-0.24	0.12	-2.10	0.04	-0.47	-0.16
Sex	0.26	0.23	1.14	0.26	-0.19	0.71
Age	0.01	0.02	0.90	0.37	-0.17	0.05
Constant	2.07	0.66	0.00	0.00	0.78	3.35
Observations	132					
Number of groups	33					
LR test vs. linear model: chibar2(01)	10.89					
Log likelihood	-147.67					
Wald chi2(4)	5.92					
Prob > chi2	0.21					

Table 4.7. Stress (Information Criterion 318).

4.7.2.2. Objective measures

A repeated measures MANOVA showed overall effects for frequency band ($F(2.28) = 233.47$, $p < 0.001$, $\eta^2 p = 0.94$), environment ($F(3.27) = 3.34$, $p = 0.034$, $\eta^2 p = 0.27$), and brain region ($F(5.25) = 23.09$, $p < 0.001$, $\eta^2 p = 0.82$). Significant interaction effects were also found for frequency band $\times$ environment ($F(6.24) = 3.78$, $p = 0.009$, $\eta^2 p = 0.49$), frequency band $\times$ brain region ($F(10.20) = 30.02$, $p < 0.001$, $\eta^2 p = 0.94$), and environment $\times$ brain region ($F(15.15) = 14.13$, $p < 0.001$, $\eta^2 p = 0.93$).

Three separate ANOVAs were then conducted, one for each frequency band (alpha, beta, theta). A repeated measures ANOVA with a Greenhouse–Geisser correction showed that

alpha power differed significantly between environments ($F(2.45, 71.04) = 7.46, p = 0.001, \eta^2p = 0.21$), as well as between brain regions ($F(1.9, 54.97) = 20.56, p < 0.001, \eta^2p = 0.42$). This also revealed a significant interaction for environment $\times$ brain region ($F(6.02, 174.56) = 18.17, p < 0.001, \eta^2p = 0.39$). For beta power, there were no significant differences for the environment, brain regions or interaction for environment $\times$ brain region. For theta power, there was a significant difference between environments ($F(2.59, 75.19) = 5.46, p = 0.003, \eta^2p = 0.16$), brain region ($F(2.27, 65.93) = 48.92, p < 0.001, \eta^2p = 0.63$) and interaction environment $\times$ brain region ($F(5.16, 149.69) = 6.22, p < 0.001, \eta^2p = 0.18$).

More specifically focused on brain regions, ANOVAs revealed significant differences in alpha power for occipital ($F(3, 87) = 51.95, p < 0.001, \eta^2p = 0.64$), lateral frontal ($F(3, 87) = 5.08, p = 0.003, \eta^2p = 0.15$), and left frontal ($F(1.47, 71.55) = 4.75, p = 0.007, \eta^2p = 0.14$) regions of the brain. For occipital regions of the brain, there was lower alpha power during exposure to green modern ($M = -0.02, SD = 0.25$) and green historic ($M = -0.12, SD = 0.25$) environments (see Figure 4.4). For the lateral frontal and left frontal, the lowest levels of alpha power were also present during exposure to the green historic environment.

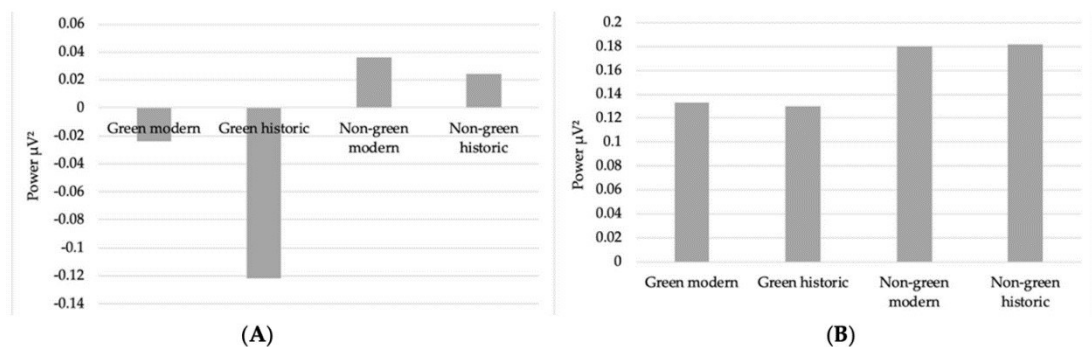


Figure 4.4. Mean occipital alpha (A) and theta (B) power across environments.

For theta power, there were significant differences for occipital ($F(2.09, 60.69) = 5.65, p = 0.005, \eta^2p = 0.16$), lateral ($F(3, 87) = 17.21, p < 0.001, \eta^2p = 0.37$), left ($F(3, 87) = 7.22, p < 0.001, \eta^2p = 0.20$), and right frontal ($F(3, 87) = 6.47, p = 0.001, \eta^2p = 0.18$) regions of the brain. For occipital regions, theta power was reduced for green modern ($M = 0.133, SD = 0.22$) and green historic ($M = 0.130, SD = 0.21$) environments, with green historic being the lowest (see Figure 6). For lateral frontal regions, green historic ($M = 0.40, SD = 0.21$) and non-green modern ($M = 0.39, SD = 0.22$) environments showed the lowest levels of theta power. For left frontal, there was reduced theta power for the non-green modern

environment ($M = 0.27$, $SD = 0.19$), and for right frontal, the green historic environment had the lowest theta power ($M = 0.22$, $SD = 0.17$).

4.8. Discussion

The current study assessed the impact of exposure to green and historic urban environments on mental well-being with a combination of self-reported psychological and physiological (EEG) measures. The research questions that were posed were: (1) Does exposure to urban environments with green and historic elements, and their combination, benefit mental well-being? (2) Do psychometric and physiological measurements agree when assessing the mental well-being benefits of exposure to different urban environments?

Descriptive analyses of subjective measures showed that exposure to all four non-traffic urban environments contributed to the recuperation of mental well-being after exposure to the traffic environment and that their restorative potential was comparable. However, among the four environments, the presence of historic elements was associated with a significantly stronger recuperation in hedonic tone and reduction in stress. This may provide evidence that exposure to historic elements is more beneficial than exposure to modern environments. In terms of mental well-being, historic elements can support mental wellbeing states, and these findings help to answer our first research question. The effect of historic environments supports and extends previous research which has shown the restorative potential of historic environments (Bornioli et al., 2018a, 2018b; Fornara, 2011; Ouellette et al., 2005; Reece, Bornioli, Bray, Newbutt, et al., 2022).

Our results found greenness to not be a significant predictor of subjective mental well-being. This could be related to the fact that according to descriptive checks, more focus was placed on historic features even when greenness was present. The most popular descriptors chosen for the environments shown were more focused on the historic characteristics rather than the green elements, even when greenness was present (e.g., 'historic', 'old'). However, when participants viewed the green environments which lacked historic features, descriptors were chosen that were more focused towards greenness. This suggests that more focus was placed on historic features even when greenness was present, which supports the subjective findings that the main effect was from historic, as per our first research question. Also, it shows that greenness is potentially valued or noticed more in the absence of historic characteristics. However, regarding preferences for environments, participants were clearer about their preference for green spaces, with most participants preferring green to urban spaces. However, they

were less decisive about their preferences for historic and modern spaces. A broader range of preferences was found for historic and modern spaces. This may suggest a potential mismatch between what is valued and what is beneficial for mental well-being. However, the current studies used urban environments that included both green and historic elements within an urban setting (Figure 4.1). Where more natural environments have been assessed, we have seen preferences for green environments, as has been reported by other authors assessing more natural green environments (Reece et al., 2022; van den Berg et al., 2003). Therefore, future research is required to assess the relative weightings of elements such as 'greenness' and historic components within a range of natural/rural, semi-rural and urban environments to assess the generalizability of the findings for promoting mental well-being through visual exposure or immersion.

The results from the objective measure (EEG) are not as simple to interpret, however, it can be highlighted that EEG is changing in response to viewing the different green/nongreen and historic/modern environments. The results showed that the presence of greenery was significant for alpha power in the occipital region of the brain. Lower levels of alpha power were recorded when participants viewed environments with greenery compared to environments without greenery. Based on previous literature, this would indicate that participants were more engaged and visually attentive when viewing the green environments as alpha is a resting state and more abundant when the brain is relatively inactive, for example with eyes closed when not processing visual imagery in the occipital (visual) cortex (Barry et al., 2007; Grassini et al., 2022; Sharma & Singh, 2015). This state could potentially be explained by the concept of 'soft attention/fascination' as described in ART (Berto, 2005; Kaplan & Kaplan, 1989), however, this is difficult to decipher and test experimentally with EEG. We might have expected an increase in frontal alpha when viewing environments that induce a relaxed state, which was not found in this study. Significant interaction effects (green x historic) were also found for theta power in the lateral frontal and left frontal regions of the brain. This increase in theta power may be reflecting a state of relaxed attentiveness, which has been shown in previous studies (Lomas et al., 2015). Furthermore, changes in EEG alpha and theta have reliably been found to be associated with relaxation and meditation (Hou et al., 2020; Roe et al., 2013; Zhang et al., 2021), which may be concordant with our results. Overall, regarding our second research question, although significant changes were detected, reflecting the sensitivity of the measures within the methods employed, we have found that psychometric and physiological measures do not always align when assessing the mental well-being benefits of exposure to different urban environments.

This study has added to the literature by assessing both subjective and objective measures of mental well-being. The lack of agreement between the physiological and psychometric findings highlights the importance of using a combination of measures when researching the benefits that environments can have on mental well-being. It also demonstrates the complexity of EEG research and interpretation of data. The use of physiological measures within this field of research is relatively new, and more studies are needed to establish their use and clarify the interpretation of results. This study has also provided a novel angle by focusing on green and historic environments and the combination of these elements, as well as highlighting the positive impact that exposure to urban historic environments can have on mental well-being.

Despite interesting findings, this study has limitations. The results from this exploratory experiment should be interpreted with caution due to the imbalance in males and females, with most participants being female (83%). Further, despite being reasonable for an EEG study, the sample size could have been larger which would have allowed us to assess specific sociodemographic characteristics which may have impacted the psychometric and physiological mental well-being outcomes. The use of a flat-screen as an exposure method in this study may have lacked immersiveness and influenced the effectiveness of exposure to environments in this study. Future studies should continue to investigate the impact of exposure to green and historic environments but adopt technology that provides a more immersive and realistic exposure, for example, virtual reality (VR). By using VR, it would be possible to create an environment which combines both green and historic features and control and isolate features of these environments. Studies have started using VR as an exposure method and the findings lend weight to the technology as a superior exposure method compared to the use of flat-screen monitors (Reece, Bornioli, Bray, Newbutt, et al., 2022). Additionally, qualitative research which highlights the green and historic environments, or features of these environments which are preferred, could be used in future research to inform and create virtual environments. Future research should continue to investigate the impact that exposure to urban historic environments can have on mental well-being, following the promising results of this study.

4.9. Conclusion

In conclusion, the psychological analyses showed support for virtual exposure to historic urban environments having a beneficial effect on mental well-being, in particular,

providing the recovery of hedonic tone and reducing stress after exposure to a stressor. The results from the physiological (EEG) measurements showed that brain activity changed as a function of viewing the different environments but were less conclusive. More specifically, the presence of greenery, compared with no greenery, was significantly associated with decreased alpha activity in occipital regions, which could be indicative of a more visually attentive and engaged state. Due to the complexity of the physiological findings, it is recommended that these results be interpreted with caution and replicated in future research, alongside other outcome measures. Future studies can build on these findings and consider using more immersive technology for exposure, e.g., VR, as well as recruiting large sample sizes with a more representative balance of sociodemographic characteristics (e.g., males and females) which would allow for subgroup analyses. This study has added to the literature by demonstrating, the impact that green and historic environments can have on mental well-being and the importance of including both subjective and objective measures when researching these environments.

Note: In preparation for this thesis, additional content from the publication which were required for the journal format can be found in [Appendix 14](#). This includes sub-sections for details of funding sources, ethics statement, authorship statement, declaration of competing interest, acknowledgements, and any supplementary materials.

4.10. Contribution to thesis

This chapter presented the second empirical study of this thesis, and the first of two pilot studies. This pilot study initially contributes to addressing thesis research question 2, 'Is virtual reality (VR) a feasible and acceptable tool for researching the multi-sensory benefits of urban greenspaces for mental well-being?'. This is addressed indirectly and by first using a simpler virtual exposure method (flat-screen) before moving onto the next pilot study which uses VR. The state of knowledge prior to this study showed that experimental studies which have used a combination of mental well-being measures are lacking and there was a gap in the field to address this and provide evidence regarding using different measures.

This study, which was an original piece of research and reviewed by recognised scholars in the field, assessed the use of virtual exposure methods for research, as well as the use of concurrent use of psychological and physiological measures in experimental testing. New knowledge was created in that this study demonstrated that the use of multiple measures of mental well-being is imperative in experimental research due to the lack of

agreement found between measures. This finding will be applied to the second pilot study (see Methods in Chapter 5) and the final experiment in this thesis (Chapter 6), whereby these studies will adopt concurrent use of psychological and physiological measures in the experimental design.

It is also important to reflect on the use of multiple measures of mental well-being adopted in this study. Here, the psychological and physiological measures were used to see if they were complimentary and provide a more comprehensive overview of mental well-being. The results from each measure diverged which may be because they are measuring different things. The UWIST-MACL scale measures an element of psychological mental well-being in regard to hedonic tone and subjective stress. Whereas EEG measures neural activity, which is linked to mental well-being, although not a direct measure. They can both be used as measures to provide a holistic overview of mental well-being.

Reflections and critical evaluation of the adopted methodology can be made here. This study used a flat-screen computer monitor as a research tool to display 2D videos of the environmental stimuli. The use of flat-screen videos was chosen as a method of exposure for the stimulus over other methods, such as photos, as they can provide a multi-sensory experience and allowed participants to hear the sounds in the environments, in addition to seeing the visual stimuli. Using videos also works well alongside the use of EEG as it can provide good temporal resolution, in that the timing of the videos and when stimuli is shown can be linked to when brain activity occurs at that time. This makes it clearer to understand the brain activity relating to the specific stimulus. However, a weakness of flat-screen videos, and similarly with viewing photos, is that the 2D stimuli lack immersiveness and realism. Other research tools such as VR could overcome this and provide a more immersive experience and therefore increase external validity, and this is explored more in the next study by comparing flat-screen with VR (Chapter 5). Moreover, participants viewing the videos may also have felt disconnected from the environments they were viewing in 2D or lost interest in viewing numerous videos one after another on a screen. The study was already long in duration due to the set-up of the EEG equipment but the study also required participants to view four videos of traffic, as the stressor stimuli, followed by the four environments which varied in greenness and historic features. This may have led to fatigue in participants which could have influenced their level of interest and energy in the study and also their responses.

It was concluded from this study that the use of EEG was complex and interpretation of the findings were difficult, which could reflect data noise. There were numerous stages

to data cleaning and analysing of the data, e.g., filtering, segmentation and referencing, to ensure correct analysis and interpretation. However, there are some limitations of EEG in general as a method for measuring brain activity. One is that EEG has poor spatial resolution in that it is difficult to determine with accuracy the specific areas in the brain where the signals originate from and there may be some overlap with signals coming from multiple areas (Burle et al., 2015). Other measures such as functional magnetic resonance imaging (fMRI) provide higher spatial resolution and are more suitable for localizing brain activity (Kim et al., 2020), however, it is also not a direct measure of brain activity and was not a feasible or practical option for this study.

Future studies could be conducted in order to develop the use of EEG as a method of measuring mental well-being and stress. When discussing stress responses, it is important to consider the hypothalamic-pituitary-adrenal (HPA) axis. When stress is perceived, the hypothalamus releases Corticotrophin Releasing Factor (CRF) which then stimulates cortisol release via the Adrenocorticotrophic hormone (ACTH). This can be measured via several physiological indicators including elevated blood pressure, increased blood glucose levels, and increased heart rate. As well as these indicators, EEG can also be linked to the HPA-axis as it is a method often used for assessing alpha and beta brainwaves which are associated with stress and relaxation. For example, lower alpha activity has been associated with higher stress levels (Neale et al., 2020). The physiological measure adopted for this study was EEG due to it being a powerful tool which allows for a detailed analysis of different brainwaves and how they change in real time in response to a stimulus.

Other physiological measures which could have been considered include cortisol swabs. Cortisol is a key biomarker in the HPA-axis, and often referred to as the 'stress hormone', which can also be easily measured through the use of swabs which are easy to administer, are low cost, and are a reliable measure in line with blood cortisol levels. Previous research has used cortisol swabs, for example to assess the effect of natural environments on stress levels in patients with severe brain injuries (Jöhr et al., 2023). However, measuring cortisol does have limitations. For example, several extraneous factors can influence cortisol including age and gender (Kudielka et al., 2004), time of day (Matsuda et al., 2012), and personality (Oswald et al., 2006). Furthermore, studies focused on stress report that peak cortisol levels are often within 25-45 minutes of stress induction (Bremner et al., 2003; Ditzen et al., 2007; Kirschbaum et al., 2000), which if applied in the current study design could have extended the duration of the study, even

more so than EEG, and not been a practical option. This would be a better option for a study design which involves longer time periods between stimuli exposure, for example, Jones et al., (2021) whose experimental design resulted in participants walking in UGS three times over three days and salivary cortisol was measured on each day (24 hours in between). Compared to cortisol measurement, EEG has strong temporal resolution in that it allows for the measurement of immediate changes in brain activity in response to a stimulus, which in this study was the different environments shown on the flat-screen monitor. EEG can provide a more in-depth and specific overview of brain activity and this was a key reason for choosing the measure for this study.

Moreover, from the physiological measure, the UWIST-MACL scale was used as the subjective measure for mental well-being (Matthews et al., 1990), however, other mental well-being questionnaires and scales exist. For example, the Warwick-Edinburgh Mental Well-being Scale (WEMWBS) is also a scale used when testing psychological states and measuring mental well-being (Tennant et al., 2007). The WEMWBS consists of 14 statements and requires participants to answer on a Likert scale what best describes their experience of each statement over the past two weeks. The WEMWBS is more suited to providing an overall rating of well-being over the previous two weeks and so was not suitable for this study which looked at acute changes before and after stimuli, which the UWIST-MACL is more suited to measuring.

An additional measure included in this study involved participants choosing from a range of descriptors which they perceived the environment to represent (e.g., green, old, cultural). The results showed that across the four environments, the descriptors chosen were biased towards built elements (e.g., historic, old, built, urban, modern), even for the environments which included green elements. This could suggest that even in mixed built and green environments, visual focus may be more towards the built elements. Future research could use eye tracking in order to investigate this further and identify where individuals focus is drawn to when viewing an environment. This, in addition to a qualitative element (e.g., brief interview at the end of the study), would also help towards understanding why individuals are visually attending to different elements and whether there could be implications for environmental design. Interestingly however, the physiological findings in this study indicated perhaps there was more visual attention and an engagement in the stimuli when greenness was present. In terms of visual attention, this may have been generally elevated when viewing green environments, while

participants may have been focusing on the more built aspects of the environment. This is a complex interaction to untangle and eye tracking may provide more clarity.

The next chapter presents the second of two pilot studies which are included as published papers. The study in the next chapter is informed by this chapter in that it continues concurrent use of psychological and physiological measures in the experimental design. However, the next chapter puts more focus on the tool of exposure and compares flatscreen with VR.

Chapter 5: Pilot study 2

Title

Exposure to green, blue and historic environments and mental well-being: A comparison between virtual reality head-mounted display and flat-screen exposure

Reference

Reece, R., Bornioli, A., Bray, I., Newbutt, N., Satenstein, D., and Alford, C. (2022). Exposure to Green, Bue and Historic Environments and Mental Well-Being: A Comparison between Virtual Reality Head-Mounted Display and Flat-Screen Exposure. *International Journal of Environmental Research and Public Health*. 19(15), 9457.

5.1. My contribution

The work in this chapter has also been published in the *International Journal of Environmental Research and Public Health (IJERPH)*. This study was also internally QR funded by the Faculty of Health and Applied Sciences at The University of the West of England (UWE), Bristol, UK, and supported by the Economic and Social Research Council (ESRC) as part of my studentship with the South West Doctoral Training Partnership (SWDTP). Acknowledgement for this study being included in this PhD thesis was also stated in the original publication. All authors gave permission for this research to be included in this thesis. I led the study in regard to methodology development, formal data analysis, data curation, writing and preparing the original draft paper, as well as reviewing and editing. Dr Issy Bray, Dr Chris Alford, Dr Nigel Newbutt, and Dr Anna Bornioli contributed to the initial conceptualization of the study and acquired funding for the study. All authors contributed to writing and editing the paper for publication.

5.2. Overview

Chapter 5 continues the focus on environments and the impact of exposure on mental well-being and presents findings from an experimental study which investigated exposure to green, blue, and historic environments through the use of virtual reality (VR) and a flatscreen (FS) computer monitor. Similarly to the previous study, this study also includes exposures which have green and historic elements. Additionally, Chapter 4 concludes that different measures of mental well-being; psychological and physiological, can give divergent results, so Chapter 5 carries this forward to also utilise psychological and physiological measures of mental well-being. This chapter also builds on the previous by introducing more qualitative data collection through the use of open-ended questions. This study focused on mental well-being as an outcome and triangulated results from psychological, physiological, and qualitative outcomes.

Similarly to the previous study (Chapter 4), this study also addressed thesis research question 2, 'Is virtual reality (VR) a feasible and acceptable tool for researching the multisensory benefits of urban greenspaces for mental well-being?'. To address this research question, this study utilised VR and compares its use as a research tool with flat-screen exposure. The study provided support for the feasibility and acceptability of using VR as an exposure method and research tool for exploring how multi-sensory UGS effect mental well-being.

The second pilot leads onto and informs the methodological decisions adopted in the final experimental study (see Methods in Chapter 6). This study investigated whether VR confers a greater benefit for mental well-being outcomes and whether it is more immersive when compared to flat-screen. Also, this study aimed to see if VR has good ecological validity and allows experimental control, in order to use it as a research tool in the final experiment presented in this thesis (Chapter 6).

As this is a published paper, there was a word limit for the journal, therefore extended methodological detail is presented in the [Appendix 15](#).

5.3. Chapter 5 research questions

RQ1: Is virtual exposure to green, blue, and historic environments associated with reduced self-reported anxiety and stress, and with physiological measures of relaxation, compared with virtual exposure to a traffic environment?

RQ2: Are there differences in effectiveness between VR and FS exposure to green, blue, and historic environments?

5.4. Abstract

Improving the mental health of urban residents is a global public health priority. This study builds on existing work that demonstrates the ability of virtual exposure to restorative environments to improve population mental health. It compares the restorative effects of green, blue and historic environments delivered by both flat-screen and immersive virtual reality technology, and triangulates data from psychological, physiological and qualitative sources. Results from the subjective measure analyses showed that exposures to all the experimental videos were associated with self-reported reduced anxiety and improved mood, although the historic environment was associated with a smaller reduction of anxiety ($p < 0.01$). These results were supported by the qualitative accounts. For two of the electroencephalography (EEG) frequency bands, higher levels of activity were observed for historic environments. In relation to the mode of delivery, the subjective measures did not suggest any effect, while for the EEG analyses there was evidence of a significant effect of technology across three out of four frequency bands. In conclusion, this study adds to the evidence that the benefits of restorative environments can be delivered through virtual exposure and suggests that virtual reality may provide greater levels of immersion than flat-screen viewing.

Keywords: restorative environments; well-being; natural and built environments; historic environments; anxiety; EEG; virtual reality; 360-degree video; immersive technology

5.5. Introduction

Exploring the mental well-being outcomes related to exposure to restorative environments is a global priority. This is due to the poor mental health conditions of global citizens, particularly in urban settings. In 2019, almost 1 billion people globally suffered from a mental health condition, such as depression or anxiety (GBD 2019 Mental Disorders Collaborators, 2022). Worryingly, around 20% of children and adolescents globally have a mental health condition (World Health Organization, 2023c). The majority of the population live in urban areas in many parts of the world including the UK (Department for Environment Food & Rural Affairs, 2019). Health can be impacted by the environment in which we live, and it has been well documented that urban environments in particular can have a negative impact on health (Sundquist et al., 2004; Ventriglio et al., 2021), including associations with increased communicable and chronic disease, mental disorders, and suicide (World Health Organization, 2010). In particular, exposure to traffic in urban environments can be stressful and have a negative impact on health (Recio et al., 2016). However, extensive research has shown that

restorative environments, such as green (e.g., parks, allotments, and community gardens) and blue spaces (e.g., lakes, rivers, and canals), can have a positive impact on well-being (Finlay et al., 2015; Foley & Kistemann, 2015; Hartig et al., 2003, 2014; Nieuwenhuijsen et al., 2017; Völker & Kistemann, 2011). Numerous systematic reviews have demonstrated exposure to green spaces and nature to be beneficial for mental well-being (Corazon et al., 2019; Tillmann et al., 2018; Vanaken & Danckaerts, 2018), as well as exposure to blue spaces (Gascon et al., 2016, 2017). There is also evidence that virtual exposure to these environments can be beneficial (Bornioli et al., 2018b; Subiza-Pérez et al., 2017, 2021). The current study assessed the effects of exposure to different environment types (green, blue, and historic) and of different modes of exposure (flat-screen (FS) and virtual reality (VR)) on psychological and physiological states on a sample of university students.

There are several theories that can explain the restorative effects of such environments. According to Kaplan and Kaplan's Attention Restoration Theory (ART) (Kaplan & Kaplan, 1989), any environment which presents the restorative properties of being away, 'soft' fascination, compatibility and extent can also offer restorative benefits. Additionally, Stress Reduction Theory (SRT) posits that being in a natural, unthreatening environment can assist in recovery from stressful situations (Ulrich, 1981; Ulrich et al., 1991).

Attention can be ultimately directed towards natural elements and away from negative emotions, leading to a reduction in stress. Despite the known negative associations between urban living and health outcomes (Mueller et al., 2017; Satherley et al., 2022), recent studies have shown that exposure to certain urban environments can be beneficial for mental well-being (Rydin et al., 2012; Taylor & Hochuli, 2015). Historic and cultural environments especially have emerged as offering the most restorative potential of urban environments (Bornioli et al., 2018a, 2018b; Brancato et al., 2022; Fornara & Troffa, 2009; Herzog et al., 2010; Hidalgo et al., 2005; Kaplan et al., 1993; Scopelliti et al., 2019; Weber & Trojan, 2018), although the restorative effect of historic settings seems to be smaller than that of natural environments (Scopelliti et al., 2019). The restorative power of historic environments can be explained, on one level, by physical features typical of historic environments, such as a high aesthetic value, moderate level of complexity and variety and biophilic design, which all are supportive of restorative perceptions (Coburn et al., 2017; van den Berg et al., 2016). In addition, historic and cultural environments tend to be containers of meaning and trigger place identity and attachment (Bornioli et al., 2018a; Bornioli & Subiza-Pérez, 2022), which are also known to support restoration (Ratcliffe & Korpela, 2016; Subiza-Pérez et al., 2021). It follows

that urban environments should be included in research into the mental well-being benefits of restorative environments, as well as green and blue spaces. Urban environments may not all have green and blue spaces, but may have historic spaces, so it is important to research these as well.

Recent evidence indicates that virtual exposure to natural environments, as well as in-person exposure, can lead to restorative benefits (Gao et al., 2019; Hedblom et al., 2019; White et al., 2018). This finding opens up several possibilities for public health improvement for populations with limited access to the outdoors (e.g., due to mobility issues or being restricted to confined environments). These populations can include, but are not limited to, prisoners, hospital and nursing home patients, and older adults with mobility issues (Altman & Bernstein, 2008; Artmann et al., 2017; Guo et al., 2019; Söderlund & Newman, 2017). Additionally, the recent COVID-19 restrictions, which led to the population being told to not leave their homes, resulted in limited access to outdoor environments. This provides a further motivation to investigate the impact that virtual environments can have on well-being.

There are several ways in which environments can be virtually presented. These can include high-definition TV, 360-degree VR, and computer-generated VR (Yeo et al., 2020). While 360-degree VR allows the user to view a real, pre-recorded environment in a 360-degree view, computer-generated VR exposes the user to a simulated, artificial environment. Virtual nature environments can create a sense of presence and immersion (Gorini & Riva, 2008; Riva et al., 2011) which can influence emotional reactions (Diemer et al., 2015) and the ability of different simulation methods to deliver these benefits has been compared. For instance, by using psychometric measures and assessing heart rate, Brivio et al., (2021) compared 360-degree VR and computer-simulated environments as tools to generate relaxation and a sense of presence in participants. Participants viewed two relaxing environments which included elements such as trees, water, flowers, bridges, houses, and natural sounds. They found no differences between the simulation methods used but this study demonstrated the feasibility of using 360-VR environments for passive viewing. Another study compared high-definition TV, 360-VR video and computer-generated VR for viewing an under-water environment (Yeo et al., 2020). They found that computer-generated VR was more beneficial for mood than 360-VR video or TV and induced a sense of presence and increased nature connectedness. Conversely, when Knaust et al., (2021) compared 360-degree VR with a PC monitor when measuring the relaxation effects of a beach scene, they found no differences between VR and PC for

psychophysiological measures (skin conductance and heart rate); however, VR was rated as more relaxing than PC when assessing self-reported relaxation. In conclusion, it is still unclear in the literature how experiences of viewing restorative green and blue environments through VR compare to simple viewing on an FS PC monitor. It is important to understand these potential differences so that the most beneficial exposure method can be adopted in future research, as well as in practice, for populations with limited access to real environments.

Taken together, there is growing evidence that virtual nature environments can support mental well-being and restoration. Turning to the well-being potential of virtual exposure to urban environments, there is some evidence that FS exposure can be beneficial (Bornioli et al., 2018b); nevertheless, there is a substantial lack of evidence on the effects of VR exposure to positive urban environments, and we aimed to address this gap by including a historic environment in our study.

A key suggestion for future research made by Knaust et al., (2021) is to explore psychophysiological responses using electroencephalography (EEG), given the limited evidence available in relation to physiological outcomes. EEG has been used in combination with VR in several contexts, e.g., in relation to neurorehabilitation (McDermott et al., 2021; Tran et al., 2022) and mindfulness training (Arpaia et al., 2022; Paletta et al., 2020); however, its use with virtual restorative environments is limited. Several studies have measured physiological and psychological mental well-being (Brivio et al., 2021; Knaust et al., 2021). EEG measurement provides an objective measure of brain cortical activity and has been proposed as an ideal measure of relaxation (Zhang et al., 2021). EEG changes have reflected improved subjective mood states when viewing green environments (Elsadek et al., 2020; Roe et al., 2013), though results may vary and change with presentation method (Wang et al., 2020). Few have gone beyond this to triangulate these measures with qualitative findings. One study did triangulate EEG with interview data (Tilley et al., 2017), although studies like this are generally lacking. This is important as triangulation can provide a more in-depth and reliable understanding of how exposure to virtual restorative environments can impact mental well-being.

The current study aimed to assess whether exposure to a potentially restorative environment (green, blue, and historic), presented either through VR or FS video, was associated with mental well-being benefits in terms of reduced self-reported state anxiety (measured by the STAI) and stress (measured by the UWIST MACL), as well as

physiological measures of improved mood and relaxation (EEG), following exposure to a stressor environment (traffic). This study also aimed to triangulate results from subjective (psychological) and objective (physiological) measures of mental well-being, and responses to qualitative open-ended questions. To address these aims, the following research questions were formulated:

RQ1: Is virtual exposure to green, blue, and historic environments associated with reduced self-reported anxiety and stress, and with physiological measures of relaxation, compared with virtual exposure to a traffic environment?

RQ2: Are there differences in effectiveness between VR and FS exposure to green, blue, and historic environments?

5.6. Methods

5.6.1. Participants

This study was conducted at a university in England, United Kingdom. Participants were a convenience sample who responded to the study advertisement through the university psychology participant pool, flyer advertisement on course noticeboards and in emails, and through social media advertisement. Recruitment took place between June and December 2021. Participants eligible to take part were healthy volunteers with self-reported normal hearing and normal or corrected-to-normal vision. Participants were excluded if they suffered from a skin allergy or hypersensitive skin, had experienced an epileptic seizure within the past 12 months, had current or previous hypertension, anxiety, psychiatric, neurological disorders, or current illness (e.g., COVID-19, and influenza), and/or were taking prescribed medication for brain or psychiatric conditions (e.g., anxiety, depression, or epilepsy).

In total, 31 participants took part in the study, of which 22 were female (71%).

Participants ranged in age from 18 to 57 years ($M = 24.32$, $SD = 8.73$). All participants were students at the university, with 27 currently enrolled on an undergraduate psychology program (87%). Half of participants indicated White-British ethnicity (52%), and 26% indicated White Other ethnicity. Participants were randomly assigned to the VR or FS condition (Table 5.1). Data from all 31 participants were included in the analysis of subjective (psychological) measures. During EEG analysis, data relating to three participants was removed due to high impedances (resistance to the flow of alternating

current) or errors in recording; therefore, 28 participants were included in the analysis of objective data.

Demographic		VR	FS
Mean age (yrs)		24.33	24.31
Sex	Female	9	13
	Male	6	3
Ethnicity	White British	8	8
	White Other	5	3
	Black or Black British – African		3
	Asian – or other Asian background		1
	Mixed – White and Asian	1	
	Not stated	1	

Table 5.1. Participants demographics per condition.

5.6.2. Design

A mixed design was employed and involved participants watching three environment videos (green, blue, and historic) and three stressor videos (traffic); see Figure 5.1. Participants were randomly assigned to watch the environment videos on a FS computer monitor or using a VR head-mounted display (HMD). Regardless of condition, stressor videos were 30 s in duration and viewed on an FS computer monitor before each environment video, with the aim of bringing participants back to a more negative mood. Subjective mood was measured after each stressor and environment video. EEG was recorded continuously throughout the experiment. Qualitative comparative assessment was made at the end after experiencing all 3 environments.

The order of presenting restorative environment videos (green, blue, and historic) was also randomized. Twelve participants viewed the green environment first, ten participants viewed the historic environment first, and nine participants viewed the blue environment first.

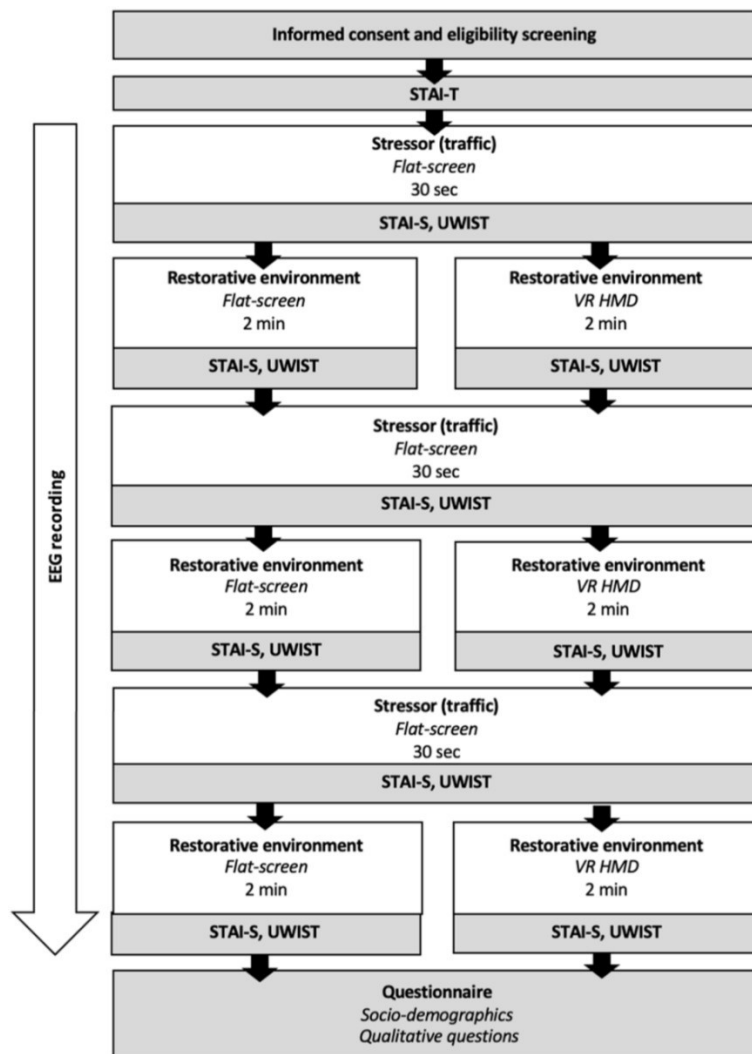


Figure 5.1. Study design and data collection. Flat-screen = Flat-screen computer monitor; VR HMD = Virtual Reality Head-Mounted Display; STAI-T = Subjective Trait Anxiety; STAI-S = Subjective State Anxiety; UWIST = Subjective Stress.

5.6.3. Exposure to restorative and stressor environments

Three videos were filmed for the experiment. These included a green environment, blue environment, and historic environment (Figure 5.2). The green environment showed an open field with vast views of the Somerset countryside. Grass, bushes, deciduous trees, and fields with sheep can be seen in the distance. The weather is clear and sunny, and the sound of the wind can be heard. The blue environment depicted a large lake (Chew Valley Lake, UK) with trees and vegetation visible on the horizon. Ripples in the water are visible and the sound of the water can be heard. The weather is cloudy with some sunshine. Behind the camera (viewable by turning around 180 degrees with HMD), there are trees, bushes and grass, as well as a public footpath following the edge of the lake. The historic environment depicted a built historic street dating from the 14th century (Vicars' Close, Wells, UK) with cobbled-stone pavements and views of a cathedral behind

the camera. The street comprises of several Grade I listed buildings. A bird is seen flying around rooftops.

The weather is sunny with some cloud and the bushes can be seen moving in the wind. Near the end of the video, some people are visible (no people are visible in the blue and green environments). Each environment video lasted two minutes. Participants viewed all environment videos either sat 46 cm away from an FS Hewlett-Packard computer monitor (57 cm × 34 cm) or using a VR HMD (Oculus Go HMD). A 30-s video of heavy traffic on an FS computer monitor preceded each of the environment videos and acted as a stressor, following similar procedures to earlier research (e.g., van den Berg et al., (2003)).

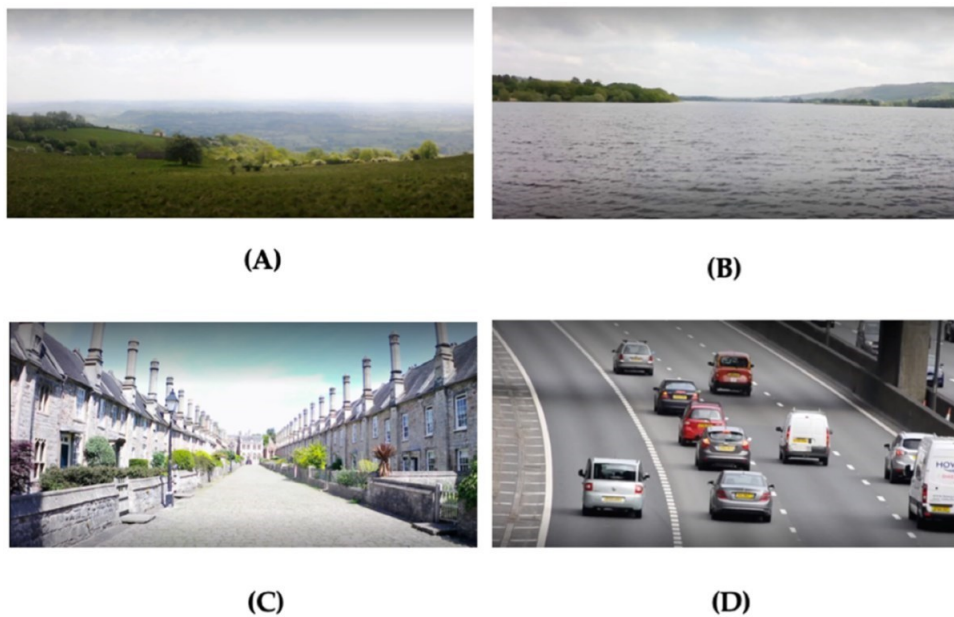


Figure 5.2. Visual stimuli. (A) Green environment; (B) Blue environment; (C) Historic environment; (D) Traffic.

5.6.4. Subjective measures

The shortened version of the State-Trait Anxiety Inventory (STAI) (Marteau & Bekker, 1992) was used to measure trait anxiety, reflecting general propensity to experience anxiety at the beginning of the experiment, and state anxiety, reflecting the level of anxiety currently experienced after viewing each environment. The trait anxiety scale includes six statements; 'I am calm, cool and collected', 'I worry too much over something that really doesn't matter', 'I feel secure', 'I get in a state of tension or turmoil as I think over my recent concerns and interests', 'I feel nervous and restless', and 'I make decisions easily'. Participants are required to answer on a 4-point scale how they feel (almost never, sometimes, often, almost always). The state anxiety scale included

includes six statements: 'I feel calm', 'I am tense', 'I feel at ease', 'I feel nervous', 'I feel relaxed', and 'I am worried'. For this scale, participants are required to answer on a 4-point scale of how they feel (not at all, somewhat, moderately so, very much so). STAI showed alpha's reliability coefficients, per environmental condition, ranging from 0.73 to 0.94.

Non-clinical mood was measured using the shortened version of the University of Wales Institute of Technology Mood Adjective Check List (UWIST MACL), which has shown to have good validity and internal reliability (Matthews et al., 1990). This scale includes four items (relaxed, nervous, happy, and sad). The output from this measure includes a score for hedonic tone and stress. For this study, only the score for stress was calculated, by combining scores for nervous and reversed scores for relaxed (Matthews et al., 1990). Stress showed alpha's reliability coefficients, per environmental condition, ranging from 0.61 to 0.76. Both scales were completed by participants on Qualtrics (Qualtrics, Provo, UT, USA, 2022) after viewing every video.

5.6.5. Objective measure

EEG is an objective measure of brain activity and can be used to assess levels of physiological stress and relaxation (Hassan et al., 2018; Tyrväinen et al., 2014), but has yet to be used to assess relaxation in VR environments (Zhang et al., 2021) and was therefore continuously recorded during this experiment. Previous research has demonstrated the utility of EEG as a psychophysiological measure including changes in affect with increased left hemisphere activity reflecting more positive mood in some studies, though not all (Cheron et al., 2016; Güntürkün et al., 2020), and pleasant emotion with increased midline theta (Bonnet & Arand, 2001). Increased stress is associated with increased beta but reduced alpha frequencies (Neale et al., 2020), and with green exposure reducing beta frequency including when associated with traffic (Hou et al., 2020; Yang et al., 2011). EEG changes in alpha, beta and gamma frequencies have been linked to changes in relaxation (Elsadek et al., 2020) and EEG has been proposed as an ideal measure of relaxation 'R-state' by Zhang et al., (2021), with increases in relaxation reflecting restorative environments, such as increased alpha in response to passive viewing of rural images (Yang et al., 2011) and increased frontal and occipital alpha when viewing green rather than urban spaces (Lomas et al., 2015). Similarly, relaxed attentional states, as opposed to loss of attention and vigilance, have been associated with increased alpha and theta (Huang et al., 2019). Differences between 'real' and simulated environments have also produced changes in EEG (Gao et

al., 2019). Based on the literature, EEG electrode grouping for this study included frontal contrasted with occipital areas, as well as lateral contrasted with medial electrodes and left with right hemisphere activity. The frequency bands assessed included theta, alpha, beta and gamma frequency ranges. Measurements were recorded using a non-invasive cap with 32 electrodes and electrode gel was used to ensure low impedances. The electrode channels were connected to a QuickAmp amplifier. BrainVision Recorder 2 was used to record the data (BrainVision Recorder, Version 1.24.0101, Brain Products GmbH, Gilching, Germany) and a sampling rate of 1000 Hz and notch filter of 50 Hz were adopted. Markers were placed on the recording when video stimuli started and finished.

5.6.5.1. Pre-processing

EEG data were analysed using BrainVision Analyzer 2 (BrainVision Analyzer, Version 2.2.0, Brain Products GmbH, Gilching, Germany). The dataset was bandpass filtered using a FIR filter with low cut-off 0.1 Hz and high cut-off 100 Hz. Pooling was conducted to create new averaged channels for electrodes with high impedances. The data were segmented into sections for traffic and restorative environments and were then further segmented into 10 s segments. Following segmentation, the data were examined for physical artefacts (e.g., muscle movements) using semi-automatic inspection and segments were removed if excessive artefacts were present. Ocular correction with independent component analysis was implemented to remove eye blinks. The data were re-referenced to the common average reference and sampling rate was adjusted to 512 Hz before segmentation was conducted to divide the data into two second segments.

5.6.5.2. Spectral analysis

Using the Fast Fourier Transform, the data were transformed from time to frequency domain. Spectral power (μV^2) was exported for theta (4–8 Hz), alpha (8–13 Hz), beta (13–30 Hz), and gamma (30–80 Hz) frequencies. Overall frontal activity was averaged over electrodes Fp1, Fp2, Fz, F3, F4, F7, and F8. Medial frontal activity was averaged over electrodes F3 and F4. Lateral frontal activity was averaged over electrodes F7 and F8. Left frontal activity was averaged over electrodes F3 and F7, and right frontal activity was averaged over electrodes F4 and F8. Overall occipital activity was averaged over electrodes Oz, O1, and O2.

5.6.6. Additional measures

Since we were also interested in the effects of personal preference for different environments and the role of immersion, we asked some additional questions to measure these concepts. A questionnaire completed at the end of the experiment, on Qualtrics, asked participants to state their preference for urban and natural environments using a 5point scale (1 = 'strong preference for natural environments', 5 = 'strong preference for urban environments'). The questionnaire also included, "To what extent do you immerse yourself within environments just to appreciate and observe them", and participants could choose 'very often', 'often', 'not sure', 'sometimes', or 'never'. After watching each environment, participants were also asked whether they were familiar with the environment. Additionally, socio-demographic data were collected (age of participant, gender, and ethnicity).

5.6.7. Qualitative outcomes

Seven optional open-ended questions were also included in the final questionnaire. These questions asked; 'How was your experience of watching the videos?', 'Is there anything in particular that attracted your attention in the videos?', 'To what extent did you find the experience realistic?', 'To what extent did you feel immersed in the environment?', 'How relaxing/engaging was it watching the videos? If it was relaxing or engaging, why?', 'Do you have any comments on the quality of the videos? Did you identify any technical issues?', and 'Do you have any additional comments?'.

5.6.8. Procedure

Upon arrival in the lab, participants read a participant information sheet ([Appendix 18](#)) and signed a consent form before taking part in the study ([Appendix 17](#)). Next, EEG electrodes were set up and attached ready for recording. Before beginning, participants completed the shortened STAI questionnaire ([Appendix 19](#)). Participants then completed the experiment (see Figure 5.1). Afterwards, participants were thanked and debriefed. Participants were rewarded for their time with the choice of course credits or a voucher. The total duration of the experiment was approximately 1.5 h. Data were analysed using IBM SPSS Version 26 (IBM Corp., Armonk, NY, USA) and Stata Version 16 (StataCorp, College Station, TX, USA).

5.6.9. Ethics

Ethical approval was granted from the Faculty Research Ethics Committee (FREC) from the University and was in accordance with the Declaration of Helsinki (see [Appendix 16](#)). To avoid cybersickness when using the VR HMD, participants were offered breaks and water in between videos. A full risk assessment was completed for the study, as well as a COVID-19 risk assessment, and were approved before commencing.

5.7. Results

5.7.1. Subjective measures

5.7.1.1. Descriptive statistics

Table 5.2 displays descriptive statistics for the subjective outcomes measured after exposure to each environment. Compared to the traffic video, state trait anxiety and stress were lower in all of the experimental conditions.

Environment	STAI-S M(SD)	Stress (UWIST) M(SD)
Traffic (1 st video)	2.45 (0.26)	2.10 (0.73)
Green	2.25 (0.24)	1.40 (0.64)
Blue	2.28 (0.22)	1.39 (0.69)
Historic	2.19 (0.26)	1.60 (0.61)

Table 5.2. Subjective outcome measures (STAI-S and UWIST) after exposure to each environment.

Participants reported their preference for natural and urban environments. Overall, most participants expressed either a strong or slight preference for natural environments (87%). Three participants had a slight preference for urban environments (10%), and one participant had no preference (3%). Participants also reported on how often they immersed themselves in environments just to appreciate them. Most participants responded 'sometimes' (58%), ten responded 'often' (32%), and three responded 'very often' (10%). Participants were not very familiar with the restorative environments that they viewed (Figure 5.3).

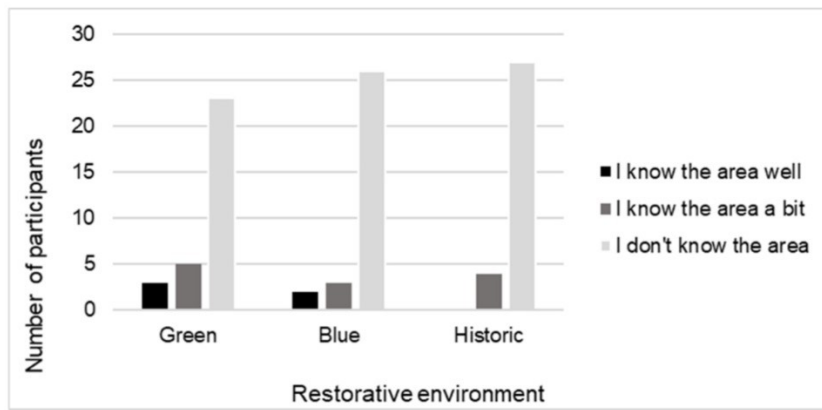


Figure 5.3. Familiarity with green, blue, and historic environment videos.

5.7.1.2. Linear mixed-effects models

Mixed-effects regression models were fitted using Stata's code mixed. These predicted differences in subjective measure scores between each experimental condition and the preceding traffic video based on arm of trial (method of virtual exposure) and controlling for age, gender, and order of experimental videos as fixed effects. The State Trait Anxiety Index model also controlled for baseline trait anxiety as a fixed effect. Table 5.3 shows changes in subjective state after exposure to the environments with lower scores reflecting reductions in perceived anxiety or stress. There were no statistically significant differences in changes pre–post exposure for anxiety and stress scores between the three environmental conditions, except for the historic environment which was associated with a smaller reduction of state anxiety compared with the blue environment. VR exposure was not statistically different from the FS exposure.

Variables	Reduction of State Anxiety (STAI-S) (β Standard Error)	Reduction of Stress (UWIST) (β Standard Error)
Green	0.02 (0.06)	-0.03 (0.17)
Historic	-0.12 *** (0.06)	0.15 (0.17)
Blue (reference category)		
VR	0.09 (0.10)	0.08 (0.23)
FS (reference)		
Age	-0.002 (0.005)	0.03 * (0.01)
Male	0.15 (0.13)	0.03
Female (reference)		
Order 1	0.19 *** (0.07)	-0.13 (0.17)
Order 2	0.17 *** (0.05)	-0.17 (0.17)
Order 3		
Baseline STAI (STAI-T)	-0.04 (0.17)	
Constant	0.14 (0.43)	-1.24 *** (0.39)
Observations	93	93
Number of groups	31	31
LR test vs linear model: chi2(5)	22.53	10.27
Log likelihood	-16.95	-110.03
Wald chi2(7)	22.53	6.13
Prob > chi2	0.001	0.52

Table 5.3. Linear mixed-effects model for psychological outcomes (STAI and UWIST).

5.7.2. Objective measure

Statistical analyses were conducted to compare brain activity between environments (green, blue, and historic) and between presentation conditions (FS vs. VR). Four frequency bands were investigated and compared (theta, alpha, beta, gamma), across several locations in the brain (overall frontal, overall occipital, medial frontal, lateral frontal, left frontal, and right frontal). Separate Mixed ANOVAs were performed which included a within-subjects factor: environment (green, blue, and historic), and between subject's factor: technology (FS or VR). Mean activity was averaged across traffic videos

to give an overall value for the stressor environment. All analyses used two-tailed significance levels ($p < 0.05$).

5.7.2.1. Theta

Two-way mixed ANOVAs were performed on the level of theta activity in frontal and occipital brain regions when participants viewed three environments either using VR or FS (technology). The main effect of the within-subjects factor ‘environment’ was statistically significant for theta activity in the overall frontal ($F(2,52) = 5.28$, $p = 0.008$, $\eta^2p = 0.17$), occipital ($F(2,52) = 6.12$, $p = 0.004$, $\eta^2p = 0.19$) and right frontal ($F(2,52) = 4.56$, $p = 0.015$, $\eta^2p = 0.15$) regions of the brain, with the highest levels of theta for the historic environment (Figure 5.4).

The main effect of the between-subjects factor ‘technology’ was statistically significant for theta activity in the overall frontal ($F(1,26) = 18.19$, $p = < 0.005$, $\eta^2p = 0.041$), medial frontal ($F(1,26) = 4.33$, $p = 0.047$, $\eta^2p = 0.14$), lateral frontal ($F(1,26) = 9.29$, $p = 0.005$, $\eta^2p = 0.26$), left frontal ($F(1,26) = 11.41$, $p = 0.002$, $\eta^2p = 0.30$), and right frontal ($F(1,26) = 11.17$, $p = 0.003$, $\eta^2p = 0.03$) regions of the brain. These regions of the brain highlighted increased theta activity in the VR condition compared to FS, for all environments. There was also a statistically significant two-way interaction: environment by technology: ($F(2,52) = 3.35$, $p = 0.043$, $\eta^2p = 0.11$) for theta activity in overall frontal regions.

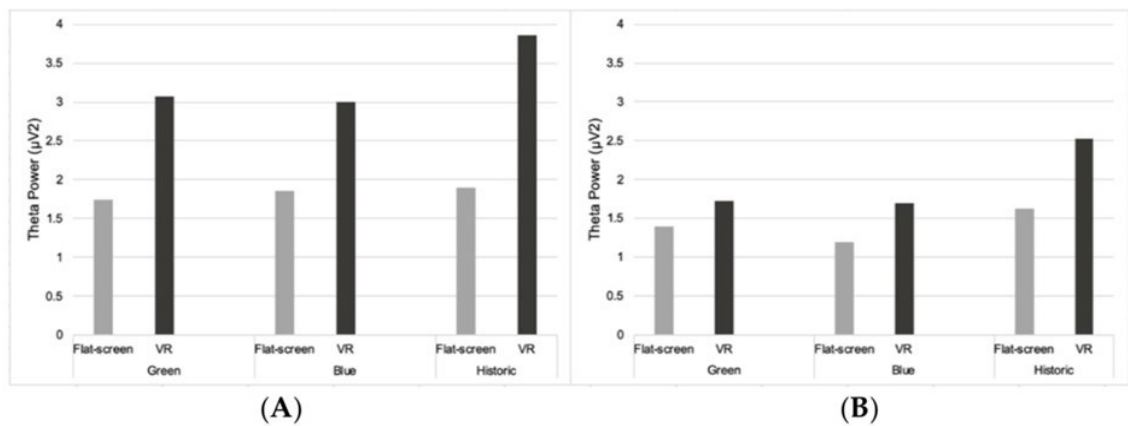


Figure 5.4. Theta power (μV^2) in the overall frontal (A) and occipital (B) regions.

Overall theta activity whilst viewing the traffic videos was higher in all regions of the brain than when viewing environments (green, blue, and historic) on a FS, but lower than when viewing environments using VR (Supplementary material in [Appendix 20](#)). One exception was that participants had higher theta activity in the occipital region of the brain when

viewing the traffic video compared to viewing the blue environment, regardless of technology condition.

5.7.2.2. Alpha

The main effect of the within-subjects factor environment was statistically significant for alpha activity in the medial frontal region of the brain ($F(2,52) = 3.99$, $p = 0.024$, $\eta^2p = 0.13$). The highest mean alpha activity in the medial frontal region was for participants viewing the historic environment using VR ($M = 0.85$), whereas the lowest mean alpha activity was for participants viewing the green environment on a FS ($M = 0.61$). The average alpha activity in the medial frontal region when viewing traffic was in between ($M = 0.72$).

Additionally, there was a significant main effect of the between-subjects factor technology in the frontal regions (overall average) ($F(1,26) = 5.44$, $p = 0.028$, $\eta^2p = 0.17$), and the right frontal region of the brain ($F(1,26) = 5.07$, $p = 0.033$, $\eta^2p = 0.16$). There was higher mean alpha activity for participants viewing all environments using VR, compared to participants viewing environments on a FS. For frontal regions (overall average), alpha activity was higher when viewing environments in VR compared to traffic, but higher activity was found when viewing traffic compared to FS. For the right frontal region of the brain, there was higher alpha activity when viewing traffic than when viewing green, blue and historic environments on FS. Viewing the historic environment with VR was the only condition when right frontal alpha activity was higher than when viewing traffic.

Two-way mixed ANOVAs were also performed to assess differences between the left and right cortical hemispheres in frontal alpha activity. There was a statistically significant main effect of the within-subjects factor hemisphere for participants viewing the blue environment ($F(1,26) = 10.09$, $p = 0.004$, $\eta^2p = 0.28$). For the green environment, there was also a statistically significant effect of hemisphere ($F(1,26) = 5.46$, $p = 0.027$, $\eta^2p = 0.17$) (Figure 5.5).

For both the green and blue environments, more alpha activity was recorded in the left frontal region of the brain compared to right frontal, for both FS and VR conditions. Additionally, when participants viewed traffic, there was less alpha activity in left frontal regions than right frontal regions. There was no statistically significant effect for hemisphere for the historic environment and no statistically significant effect of technology or interaction effects were found for any environment.

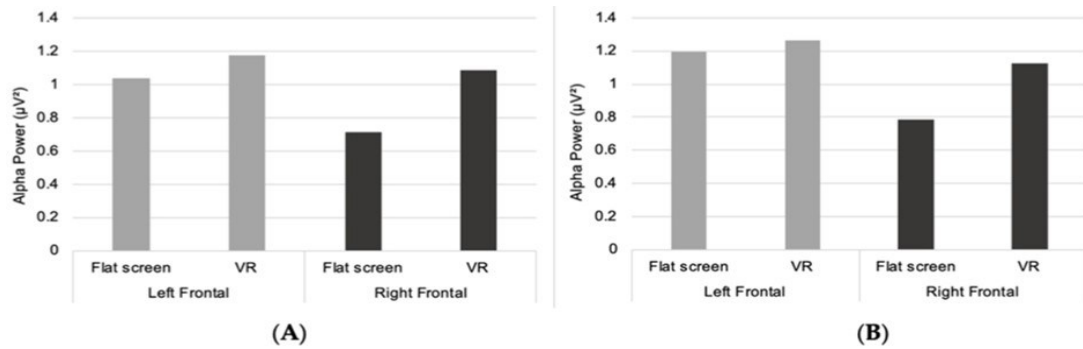


Figure 5.5. Hemispheric differences in frontal alpha power (μV^2) for green (A) and blue (B) environments.

5.7.2.3. Beta

No statistically significant main effects or interaction effects were found when assessing beta activity across frontal and occipital regions of the brain. As with theta and alpha, there was overall increased activity for the VR condition compared to FS, but there was no significant effect of technology. However, interestingly, beta activity was reduced during the VR condition, compared to FS, when participants viewed the blue environment. Levels of beta when participants viewed traffic were lower than when viewing the blue environment, regardless of exposure type (VR or FS).

5.7.2.4. Gamma

Two-way mixed ANOVAs were also conducted on the level of gamma activity. There was a statistically significant main effect of technology in the frontal regions (overall average) ($F(1,26) = 4.97, p = 0.035, \eta^2p = 0.16$) and medial frontal region of the brain ($F(1,26) = 6.07, p = 0.021, \eta^2p = 0.19$). Higher gamma activity was observed in these areas of the brain when participants viewed all environments using VR compared to participants viewing on a FS.

Additionally, for frontal regions (overall average), higher gamma activity was recorded for participants viewing the traffic video compared to viewing all FS environments, but lower compared to VR experiences. This was similar for medial frontal activity, except gamma activity whilst watching traffic was lower than viewing a green environment (regardless of technology condition). No statistically significant results were found for the main effect of environment or an interaction effect: environment by technology.

5.7.3. Qualitative outcomes

In analysing these open-ended questions, we created four categories from the seven questions/prompts (detailed above in the Methods section). These were: (1) experience

and immersion (questions 1,3,4); (2) attention in the experience (question 2); (3) relaxing and/or engaging (question 5); and (4) technical/quality related (questions 6,7). The data below draw upon direct quotes. We used a system to identify the condition they were assigned (VR or FS), followed by their gender (M or F) and finally their age. For example, VR-M-45, refers to a male, aged 45 in the VR condition.

Considering the first category (experience and immersion), participants from across both conditions (VR and FS) reported the experience of watching the environments (green, blue, and historic) to be “enjoyable and interesting, some of them were very calming” (FS-F-19) and “the ones of nature were very relaxing in comparison to the ones of traffic” (VR-F-18). The content of the scenes also generated positive comments, with one participant in the VR condition stating: “Virtual reality videos were very pleasant, the nice weather in all of them helped me feel at ease” (VR-F-19). Comments related to the relaxing nature of the 360 videos were echoed across both the FS and VR conditions, with participants reflecting: “I really enjoyed both the countryside and water based environments—I felt significantly more relaxed during those” (FS-F-20), “The experience was good, found the nature videos a lot more relaxing than the traffic ones” (FS-F-21), “Interesting and generally calming” (VR-M20), and “I found the videos on the VR headset very relaxing, and in a much calmer environment than watching the busy roads” (VR-F-20).

In relation to feeling immersed, the VR condition created far more detailed responses. The FS environment elicited 278 words in total comments with the VR condition eliciting 612 words of comments. The FS condition participants reported the realism and immersion to be: “somewhat” (FS-F-35), “not really” (FS-F-29), “fairly” (FS-F-20), and “slightly” (FS-F-22). Additionally, one commented: “[it was] pretty realistic for a lab experiment” (FS-F-21). The FS condition was not without more positive comments related to immersion and realism, with several comments suggesting: “Well I suppose it is realistic enough” (FS-F-49), “very, there was a lot to look at and take in within all the videos/scenery. With the sea scene especially as you could just watch the waves rather than looking around at everything else” (FS-F-19), and “very much with the residential area and the video with the water” (FS-F-35). Similarly, the VR condition also generated positive comments suggesting that participants felt: “Quite immersed, the sound definitely made it more immersive and the response to movement, I felt like I could’ve talked to the people like it was a live recording instead of recorded at an earlier date” (VR-M-22), “moderately so” (VR-F-20), “not sure” (VR-M-28), and “I didn’t feel very immersed in the environment. I think maybe I was too aware that what I was seeing

wasn't real and that I couldn't see my actual surroundings was perhaps a little disconcerting" (VR-F-28). However, these were the only negative comments related to the VR exposure, with far more positive comments overall, such as: "[...] the VR videos they definitely had my whole attention" (VR-F-20), "VR felt much more realistic" (VR-F-20), and "very realistic, the sound really made me feel like I was there, was feeling very similar to being there" (VR-M-22).

The second category was related to attention in the experience. The FS experience generated several comments about the stressor videos (i.e., cars) while the VR experience generated none. The FS comments related to the scenery (green, blue, and historic) included: "The video of the sea and the final video of the green area did remind me of where I am originally from (Sussex) [...] the green especially did remind me of the south downs" (FS-F-19), "I liked the water-front as well as seeing the old man taking a walk on the stone road" (FS-F-18). The VR condition generated more detailed and specific comments related to attention. Two specific examples were: "I found whenever there were people in the videos my attention was drawn to them" (VR-F-28) and "the horizon, was a focal point for me" (VR-M-28).

For the third category, relaxing and/or engaging, comments from participants in the FS condition suggested that they were mixed: "the video with the massive green area was not relaxing, I felt alone" (FS-F-35) and "it was quite relaxing, felt like it was real because I usually go to the forest just to refresh when I'm happy or sad" (FS-F-22). Additionally, one participant suggested the lack of elements like wind or smells limited their relaxing in the FS environment(s), saying: "not engaging as I cannot feel the wind or smell the animals in the country [...] relaxing a little as it allows you to reflect when looking onto the countryside" (FS-F-29). On the other hand, some FS participants felt their experiences were relaxing stating: "The scenery videos were very relaxing, although at first, I thought I should be looking for something in particular or there may be something that suddenly happens or changes [. . .] this meant the final scenery ones were more relaxing than the first" (FS-F-18) and "very relaxing to watch the natural environments but less so the urban ones" (FS-F-20). Some felt the FS environments with less going on were linked to them feeling relaxed: "Relaxing - rural areas more chilled less to observe" (FS-F-30), with some feeling less going on was linked to lack of engagement, stating: "The countryside and lake ones were very relaxing. Not as engaging though" (FS-F-20). Comparing this to the VR condition, all participants revealed they were/felt relaxed, and referred to several

physical elements of the VR-360 experiences. Comments included: “Very relaxing as you could imagine being there, listening to the wind blowing and the reflection of the sun going behind the clouds” (VR-F-57); “it was relaxing as it gave me a time to relax and be creative and think fun thoughts like touching the grass and cobbles and imagining being on a day out adventure on my own in the sun” (VR-M-22); “very I liked being able to look around and could hear the wind, water” (VR-F-20); “very relaxing due to the nice environments, with very few other people around” (VR-M-21); and “the naturalistic environments were particularly relaxing, they had a calm centred quality that I felt allowed you to let go of thoughts more easily” (VR-M-28).

Finally, the fourth category, technical/quality, raised issues of the fidelity and quality of the VR condition, with several comments about the material/videos being “ever so slightly blurry” (VR-F-20); “the VR footage was a little grainy” (VR-F-28); and “the videos on the VR could have better quality” (VR-M-22). The FS condition yielded several comments related to the video(s) being “good” and that “they were all high quality and realistic and I had no technical issues” (FS-F-19), but the participants also suggested there was room for improvements, stating: “The quality was a little poor in some” (FS-F-20) and that the “nature videos were a little bit blurry” (FS-F-21).

5.8. Discussion

This study investigated responses to exposure to different environments (green, blue, and historic) compared with a stressor video, with different tools (FS and VR).

Measurements included psychological, physiological, and qualitative outcomes. Two research questions were posed; (1) Is virtual exposure to green, blue, and historic environments associated with reduced self-reported anxiety and stress, and with physiological (EEG) measures of relaxation, compared with virtual exposure to a traffic environment? (2) Are there differences in effectiveness between VR and FS exposure to green, blue, and historic environments?

Results from the subjective measure analyses showed that exposures to all the videos of restorative environments were associated with reduced self-reported anxiety and stress. There was little to differentiate the effectiveness of these three environments, except some evidence of a smaller reduction in anxiety following the historic environment. These results were supported by the qualitative accounts, which suggested that the restorative environments were relaxing and calming, but the historic environment

perhaps less so than the green and blue environments. Findings for the physiological (EEG) measurements were less conclusive. For two of the frequency bands (theta and alpha), significant differences were found between the experimental environments (green/blue/historic), with activity being the highest for historic environments. For the other two channels, there was no evidence of any differences between the environments. In relation to the role of mode of delivery, the quantitative subjective measures did not suggest any effect, while for the EEG analyses activity was generally higher for VR than FS, and there was evidence of a significant difference across three of the four frequency bands. Whilst the subjective ratings of stress (UWIST MACL) and anxiety (STAI-S) did not result in significant differences between presentation formats (FS contrasted with VR), these EEG changes were aligned with some qualitative descriptors reflecting greater experiences of immersion, presence and realism for the VR presentations resulting in greater levels of cortical brain activity (EEG power). Increased alpha and theta with VR exposure may also reflect greater 'relaxed attentional states' as proposed by Lomas et al., (2015).

The self-reported psychological responses, which improved in the green, blue, and historic conditions compared with the traffic video, confirmed previous research that exposure to green (Nieuwenhuijsen et al., 2017), blue (White et al., 2018) and historic (Bornioli et al., 2018a) environments can offer mental well-being benefits, and partially answered research question 1. The blue environment was associated with a larger reduction of state anxiety compared to the historic condition, and was not statistically different from the green condition, indicating that reduction of anxiety is maximized in natural environments, as opposed to historic built ones (Scopelliti et al., 2019). Conversely, where the EEG results suggested there were differences in restorative effect between the environments (theta and alpha), it was the historic environment that appeared to have the largest effect, an apparent contradiction in the findings for research question 1. It is possible that historic settings can support other forms of mental well-being benefits, such as triggering soft attention stimulation or cognitive engagement (Bornioli & Subiza-Pérez, 2022) again reflecting relaxed yet attentional states (Lomas et al., 2015), rather than stress reduction and relaxation which are properties of natural environments, and that these were detected by the EEG measurements.

An increase in alpha activity can reflect decreased cortical activation and be likened to relaxation with alpha reflecting a resting frequency for cortical activity (Kubitz & Pothakos, 1997) and increased cortical activity may reflect greater engagement. Our

results are consistent with other studies which have found green spaces to be associated with increased levels of meditation (Roe et al., 2013) and provides partial support for increased alpha activity indicating increased relaxation and reduced visual processing (Grassini, 2022; Neale et al., 2020; Sharma & Singh, 2015). Our study also showed significant increased alpha activity in the left frontal region when participants viewed the green and blue environment, regardless of exposure type (FS or VR). This may be explained by higher levels of alpha representing increased cortical activity, as opposed to inactivity, and fit with positive emotions associated with being processed in the left hemisphere, and less positive emotions associated with the right hemisphere (Alves et al., 2008). Although significant increases in subjective hedonic tone/positive mood state were not found in the current study, limiting comparative assessments with EEG, alpha levels overall in the traffic condition were higher than for FS natural environments overall. Earlier research has shown differences between viewing real environments and video presentation (Huang et al., 2019). There was further support for the significant increase in medial theta with VR presentation, perhaps reflecting more positive mood overall (Cheron et al., 2016), linked to increased engagement and immersion in our study. Previous studies have shown significant changes in beta activity when participants view blue spaces (Huang et al., 2019) and green spaces, compared to urban settings (Neale et al., 2020). Further, beta reductions were reported for green environments (Neale et al., 2020) and reflected reduced traffic induced stress when viewing green environments (Yang et al., 2011). There were no significant changes in beta activity in the present study which therefore differs from previous literature and does not provide support for reductions in beta activity reflecting reductions in stress. Nevertheless, some other studies have also found no significant differences in activity between environments which varied in grey, green, and blue space (Gao et al., 2019; Wang et al., 2020) and may reflect the developing status of these relatively new research applications. In regard to historic environments, to the best of our knowledge this is the first study which assessed EEG outcomes in these settings, hence the findings that historic environments can trigger increased alpha and theta, reflecting improved cortical engagement and relaxation, is novel and warrants further research.

While the psychological measures did not detect any difference according to mode of delivery, limiting comparisons, the physiological measures (EEG) show a significant effect of technology. Increased brain activity was recorded across multiple frequencies when viewing all environments through VR, compared to FS exposure and baseline stressor (FS traffic). This effect of technology is consistent across theta, alpha and gamma

frequencies, lending weight to this finding in response to research question 2. In previous studies, meditation and relaxation have been associated with increased occipital gamma activity (Cahn et al., 2010; Hou et al., 2020). However, this is not consistent with the findings from the present study which showed increases in frontal gamma activity when participants viewed the environments through VR compared to FS, but no significant difference for occipital gamma. However, as mentioned, the significant increases in both alpha and theta frequencies, reflecting a state of relaxed alertness, are supported by previous research (Lomas et al., 2015).

We suggest that the different findings for psychological and physiological measures could potentially be explained by considering evolution and genetics. As animals, humans have an innate tendency to be in nature and connect with nature, which is explained by the biophilia hypothesis (Wilson, 1984). This may be why the enhanced immersiveness provided by VR had an effect that could be detected physiologically through brain activity changes which may be subconscious, but not through self-reported measures, which measure conscious perceived psychological state. Further, genetics may play a role and there may be genetic differences among people's connection with nature (see, for example, the twin study by Chang et al., (2022)). At the same time, it is possible that historical sites in particular can engender a sense of awe and wonder (Bornioli et al., 2018b; Fornara, 2011), which may explain why this study uncovered an effect of the historic environment for EEG measures. Knowing that most of the population live in urbanized areas (United Nations Department of Economic and Social Affairs, 2012), and that the amount of urbanization in our hometowns can influence our preferences for environments (Chang et al., 2022), this is a finding which can inform policies for healthy cities. Although beyond the scope of this paper, further research could investigate the association between individual objective brain responses to different environments and subjective environmental preferences, dwelling location and other person-specific factors.

In relation to research question 2, no significant effects were found for technology (VR vs. FS) in terms of self-reported anxiety. This could be explained by participants potentially having some anxiety with using VR headset, as novel technology, which may have cancelled out any effects of the more realistic exposure. One participant stated, "...I couldn't see my actual surroundings was perhaps a little disconcerting" (VR-F-28). This explanation can also be viewed in a positive light, in that VR did not increase anxiety in participants, meaning VR did not create a negative experience. Further, it was reported

that no participants suffered symptoms of cybersickness during the study, which is a surprising finding knowing the prevalence of cybersickness effects of VR (Stanney et al., 2003). However, some research has stated that cybersickness happens after 10–15 min of immersion (DiZio & Lackner, 2000), which may be why the two minutes of exposure at a time in this study did not have an effect.

Additionally, in relation to research question 2, this study has shown through physiological measures and qualitative responses that there are differences between exposure type for viewing green, blue, and historic environments. Taken together, the qualitative data (captured through post-experience surveys) revealed that participants preferred the VR experience for promoting feelings of relaxation, in addition to a sense of realism and ‘being there’ (ecological validity). This can lead to increased perceived presence (Han et al., 2022). The FS condition led to more comments that suggested lower levels of realism or immersion, but in terms of attracting attention, the FS and VR conditions elicited similar responses and replies. Qualitative responses provide most support for there being a difference in technology (VR vs. FS), which was consistent with our physiological findings.

Qualitative responses can be used to further explain the differences between technologies. VR provides a space to relax but also be attentive (e.g., focus on a particular aspect of that environment, such as trees and wind, etc.). This is consistent with the EEG findings in relation to the increase in alpha and theta activity which can reflect ‘relaxed attentiveness’ (Lomas et al., 2015). Theta power increases have also been explained as underlying focused attention and ‘getting in the zone’, and alpha increases reflecting focused attention, with local inhibition of unwanted cognitive activity such as distractors, in successful sports performance (Cheron et al., 2016). This would indicate for the present study that participants were in a state of focused attention whilst viewing environments through VR compared to FS. This could be beneficial for populations such as people with autism by providing a means to relax and escape into a virtual space (Maskey et al., 2014), whilst also being able to focus and direct attention.

Another interesting finding was that participants in the VR condition generally gave more qualitative feedback compared to those in the FS condition. Furthermore, participants in the VR condition only talked about the VR environments in their qualitative responses and not about the traffic videos, whereas the participants in the FS condition also talked about the traffic videos. It is also important to recognize what VR can take away as well

as what it can provide (e.g., shutting out distractions in the world around us). This could be an important attribute for exposure to an environment, to maximize the restorative potential.

This study has provided a novel approach by triangulating psychological, physiological, and qualitative outcomes. Firstly, this study highlights the importance of, and differences between, the choice of measures used in research to investigate the mental well-being benefits of different environments. We found agreement between the psychological measures and qualitative perspectives, although the physiological measures (EEG) did not fully mirror the quantitative psychological results. Secondly, a comparison has been made in this study between FS and VR as exposure types for viewing environments. This investigation also served as an exploratory study for the use of VR as a method of exposure to environments when assessing their mental well-being potential. Clear differences have been found in EEG recordings between the exposure types, supporting the use of VR as an immersive exposure option in future studies. Thirdly, our results provide some evidence for the positive impact of exposure to historic environments which should be investigated further as it has particular potential for improving the mental well-being of urban populations.

This was a randomized experiment with good balance between the two arms of the trial. However, the sample size in this exploratory study was small though reflecting typical EEG studies, and so the results should be interpreted with caution. The quality of the videos shown was commented on by participants viewing on FS, as well as through VR. It was highlighted by some that videos were blurry and so the quality could have been improved. The Oculus Go headset was chosen for its good usability; however, future research should consider using better quality VR technology and filming equipment for recording videos of environments. Overall, the results suggest that VR is a worthwhile technology, and it warrants further investigation in future studies. Second, there was an imbalance in the number of males and females in the conditions of the experiment. There were more males in the VR condition ($n = 6$) compared to the FS condition ($n = 3$) and more females in the FS condition ($n = 13$) compared to VR ($n = 9$). Furthermore, due to convenience sampling as well as recruitment through the university's psychology participant pool, which is predominantly made up of female students, the majority of our participants were female. This may have impacted the results as previous research has found that female participants were more excited about using new technology (such as VR), and this technology triggered more positive emotions than with males (Dirin et al., 2019). Future

research should focus on including all sexes and examining differences in relation to the mental well-being benefits of exposure to virtual environments. Third, the novelty of using VR for the first time may have influenced the experience and results of the participants in the VR condition. Future research can counterbalance for this or only use either first time users or experienced users of VR, or by adding an initial adaptation trial where data were not recorded, but participants can adapt to the novel technology and laboratory protocol. Additionally, participants were seated whilst watching all environments, and this may not have been as immersive as if participants were standing up and physically turning around in the virtual environment.

It should be noted that research into the effects of exposure to different environments using EEG is still in the early stages and these results should be taken as preliminary. There are several competing models that can explain the EEG results and more research is needed to interpret them. Additionally, frequencies coming from the VR headset in proximity to the EEG electrodes could be an artefact and may explain the consistent increase in activity recorded across some frequencies. Some previous research has examined the impact of head mounted displays (VR) technology on concurrent EEG recording but found that whilst there was some electromagnetic interference at higher frequencies, the lower frequencies investigated in the current study (theta 4–8 Hz, alpha 8–13 Hz, beta 13–30 Hz, gamma 30–80 Hz) were largely unaffected, though line noise (50 Hz) could be a factor but was effectively filtered out in our analysis, and a 90 Hz refresh rate for one headset impacted higher frequencies (Weber & Trojan, 2018). Future studies might usefully include an additional baseline EEG comparison with and without the VR headset being active in order to isolate and quantify the effects of the VR technology alone on EEG frequencies.

5.9. Conclusion

In conclusion, the psychological and qualitative analyses provided evidence to support the beneficial effects of virtual exposure to natural and built environments on anxiety. There was no apparent difference between the green and blue environments, and some limited evidence that they may provide greater restoration than the historic environment. However, further studies with a wider range of environments and larger sample sizes are needed, also acknowledging the role of individual preferences for particular environments. We note that the novelty of the VR technology may counteract any potential relaxing effects but was found to be promising as a method of presenting potentially restorative environments. Physiological (EEG) findings are harder to interpret

but tended to suggest higher levels of brain activity when using VR compared to FS viewing, and in historic environments compared to natural ones. These findings possibly indicate greater relaxed engagement with the environments with the VR technology, and therefore greater immersion. This lends weight to the potential for developing VR technologies to be used to research the effects of exposure on a wide range of different environments, and to deliver these benefits to subgroups of the population who are not able to access such environments (such as prisoners, and those with impaired mobility).

Note: In preparation for this thesis, additional content from the publication which were required for the journal format can be found in [Appendix 20](#). This includes sub-sections for details of funding sources, ethics statement, authorship statement, declaration of competing interest, acknowledgements, and any supplementary materials.

5.10. Contribution to thesis

The current state of knowledge in the field shows there is significant support for the mental well-being benefits of restorative environments, although there are limited research studies which have looked at the different tools of exposure. Here, flat-screen was compared with VR as a research tool, which is one area where studies have lacked focus. In support of the previous pilot study (Chapter 4), this study also adopted the use of both psychological and physiological measures, confirming that both should be utilised in experimental research in the field due to the lack of agreement between measures. This study also took this a step further in suggesting the importance of triangulation and including a qualitative outcome as well. In answer to the overarching thesis research question 2, the study in this chapter provides support for the feasibility and acceptability of using VR as an exposure method and research tool for exploring the multi-sensory benefits of restorative environments for mental well-being. This study added new knowledge in regard to using VR as a research tool when looking at restorative environments and the impact on mental well-being. Similarly to the studies presented in Chapters 3 and 4, this study was also an original piece of research which was successful through peer-review by recognised scholars in the field and was subsequently published.

As with the previous studies presented in this thesis so far, there are several lessons that can be learnt from conducting this experiment, as well as reflections on the methodology of enquiry and actions which are taken forward into the next experimental study (Chapter 6). A key outcome is that this study provided support for the conclusions reached in the preceding pilot study (Chapter 4), which was that there are disagreements in results when comparing physiological and psychological measures.

With this outcome, it is important to not draw an incorrect conclusion based on one type of measure and to not emphasise one result over another. For example, a Type 1 error (false positive) could be made on the basis of the physiological measure alone as this measure generally showed significant findings. Additionally, it is important to not also make a Type 2 error (false negative) based on the psychological measures alone and state that there is no statistically significant evidence when actually there is with the physiological measure. By using both psychological and physiological measures of mental well-being, it allows for a balanced judgement to be made in regard to which manipulations may be more or less sensitive, whether that be the type of environment (green, blue, historic) or how the stimuli were presented (VR or flat-screen). Overall, it is clear from this study that psychophysiological responses are complex and physiological and psychological measures both need to be considered and concurrently used in future research.

For the physiological measure, this study again utilised EEG as a method for measuring mental well-being and this time used it alongside a VR HMD. Whilst this was successful practically in that both types of equipment fitted on the participants heads concurrently, it was a cumbersome amount of technology. To avoid this but still measure EEG whilst participants viewed environments, some studies have adopted the use of mobile EEG in real-world settings (Petukhov et al., 2020). Mobile EEG can allow for brain activity to be measured in a real-world setting where the participant can wear a lightweight and mobile device and not be restricted by wiring, as in a laboratory setting. Another study used mobile EEG with young adults to investigate the effects of walking and crowding in indoor and outdoor urban environments (Mavros et al., 2022). The study reported that due to practical restraints, they were unable to assess the crowdedness in greenspaces and suggested this focus for future research. Along with the theme of 'sharing a space of others' which was identified in the qualitative study of this thesis (see analysis in Chapter 3), the next chapter (Chapter 6) focuses on crowding and the impact that other people being present in a greenspace can have on mental well-being.

If mobile EEG was feasible, being in a real-world setting such as a green environment would also incur challenges. It is very difficult to control for certain external factors in real-world settings and these may influence the measurements taken and therefore the interpretation of results and conclusions. External factors could include factors such as the weather, noise, and unpredictable events such as protests or sport activities. If this design had been implemented into this study, it would have involved participants visiting

three separate environments (green, blue, and historic) which are not closely located to one another and so would have involved travel time and costs. There would also have been a lack of control over the environments, such as the weather which could have changed across settings, or how busy there were with people. This could have influenced how participants felt about the environments in regard to their stress levels and mental well-being, and therefore not made it possible to isolate the effect of the environment itself.

There are also other physiological measures which could be used instead of EEG which are less invasive, quicker to administer, but could still be compared with psychological, self-report measures of stress and mental well-being. A disadvantage of EEG is that it is fairly involved and requires a time-consuming set-up. In addition, it was physically cumbersome with a VR HMD, as found out in this study. Placing the HMD on top of the EEG cap displaced some electrodes and the movement altered the signal strength, which meant that more time was needed to correct the placement and signal. Other physiological indicators such as heart rate and blood pressure are less invasive to administer through the use of wearable devices (e.g., arm and wrist cuffs) and are reported generally as good indicators of stress (Kim et al., 2018; Kulkarni et al., 1998). Due to these advantages, for the final experimental study in Chapter 6, heart rate and blood pressure are adopted as the physiological measures of mental well-being.

Another reflection of this study is in relation to the chosen qualitative data collection method. This study included seven open-ended questions at the end of the questionnaire. These were designed to be brief as the study duration was long and participants could have been fatigued at the end of the study. By adding in these qualitative questions, it added to the quantitative measures and allowed for triangulation of the results. As demonstrated in Chapter 3, a qualitative methodology can provide depth and detail and aid in the interpretation of data. However, by including optional questions, this can create challenges. For example, it meant that participants could respond as little or as much as they desired, and this resulted in some participants not responding at all. The majority of participants did respond but their answers diverged in the extent of detail provided. In reflection, employing a different method such as a compulsory semi-structured interview could have helped to overcome this. This would have allowed for opinions of all participants to be represented in the results, and also potentially resulted in more expansive responses. When conducting interviews, prompts and follow-up questions can be included which allow for expansion of opinions and a deeper reflection (Jiménez &

Orozco, 2021). Learning from this, a semi-structured interview is included at the end of the experimental procedure of the study presented next in Chapter 6. This follows on from this study by including a qualitative element but further develops it by allowing for all participants to be presented in the qualitative results and for rich and detailed data to be recorded.

The next chapter is the final empirical study included in this thesis and is informed by the findings of the previous three studies (Chapters 3,4,5). The topic of the final experimental study is informed by the findings of the qualitative study presented in Chapter 3, whereas the two pilot studies (Chapters 4 and 5) inform the methods adopted in Chapter 6.

Chapter 6: Final experimental study

Title

The presence of people and crowding in urban greenspaces: examining the impacts on social connectedness and perceived restorativeness

6.1. Overview

This chapter presents a final empirical study in this doctoral thesis and is a traditionally written chapter and not a published paper. This study answers thesis research question 3, 'How does crowding in urban greenspaces impact social and perceived restorative outcomes?'. Similarly to the rest of this thesis, a focus is kept on environments and their impact on mental well-being, but this study takes a narrower angle and looks into the effect that other people being present (subjective crowding) in an UGS can have on mental well-being, the perceived restorativeness of these spaces, and feelings of social connectedness as a sub-dimension of mental well-being. This angle is informed by one of the key findings which is identified in the previous qualitative study (Chapter 3). One of the themes identified in the qualitative study, which was a key aspect of UGS for mental well-being for multiple age groups, was titled 'sharing a space with others'. This theme explained that UGS are places that are sometimes sought out with the aim of being away from other people, while others saw it as an opportunity to meet other people. The theme also encompassed that an experience of a space is different depending on if you visit with other people versus going alone. Additionally, this study found that crowding and being able to get away from other people to escape in an UGS was important for users of all age groups. Being informed by these findings, the study presented in this chapter aimed to focus more on this social aspect of UGS, social well-being, which appears to be an important factor to consider in relation to how UGS can be beneficial for mental well-being. This study looks specifically at crowding and the impacts that this can have.

This study adopts an experimental design using VR as a research tool, and implements psychological, physiological and qualitative methods for data collection and analysis. Whilst the topic of this study has been informed by the findings of the qualitative study (Chapter 3), the methods are supported by both of the pilot studies previously presented in this thesis (Chapters 4 and 5). The importance of using multiple measures of mental well-being in experimental research in this field, as well as the feasibility of

virtual visual methods, is supported by pilot study 1 (Chapter 4). The use of VR in this study as a research tool for environment exposure is supported by pilot study 2 (Chapter 5) which demonstrated it to be a feasible and reliable tool for environment and mental well-being research. Commensurate with Chapter 3, this study also explores whether age may moderate the impact of different levels of crowding on restorative and social outcomes of UGS experiences.

6.2. Abstract

UGS can provide multiple benefits including stress restoration, facilitating social cohesion, and improving mood. However, experimental research looking at the mental well-being benefits of UGS most often focuses on spaces free from people in order to eliminate their potential influence as a confound. This is problematic for generalising to real world settings as visits to UGS are rarely in solitude. Therefore, this experiment investigated whether other people in an UGS impact perceived restorativeness and feelings of social connectedness.

In a repeated measures design, 58 participants were exposed first to a stressor and subsequently to three UGS in VR which varied only in the number of people present (none, few, lots) and quantitatively measured psychophysiological indicators of mental well-being, perceived restorativeness and social connectedness. Brief interviews were also conducted at the end of the experiment to explore issues of felt presence and preference for the different environments. Quantitative data were analysed with linear mixed-effects models and qualitative data with framework analysis.

Significant interaction terms in the linear mixed models revealed that after viewing a stressor, viewing environments with no, or few, people in them were associated with greater stress reduction, greater differences in perceived restorativeness, and greater reductions in diastolic blood pressure, than viewing the environment with lots of people in. However, viewing environments with few, or lots of people in them, were associated with greater increases in energy and higher social connectedness compared to the environment with no people. Qualitative analysis identified five themes: social comfort in less crowded spaces, experience of being alone as both positive and negative, ways for navigating crowding, the importance of sounds, and VR as an immersive tool. Overarching these themes, preferences for the number of people present was conditional on needs of the individual at a particular point in time.

The findings indicate a potential trade-off between different dimensions of mental well-being, restorativeness, and social connectedness in more and less crowded UGS. This extends previous experimental work and suggests that the presence of people should be a component which future research considers more thoroughly in experimental designs.

6.3. Introduction

Extensive research has demonstrated the numerous benefits that UGS can provide for mental well-being including attention and stress restoration, reducing depression, improving cognitive health and mood, and higher life satisfaction (de Vries et al., 2016; Hong et al., 2019; Neill et al., 2019; Ohly et al., 2016; Triguero-Mas et al., 2017).

The underpinning theoretical frameworks commonly referred to regarding UGS and health and well-being outcomes are Attention Restoration Theory (ART) (Kaplan & Kaplan, 1989), and Stress Recovery Theory (SRT) (Ulrich et al., 1991). Firstly, ART explains how an environment can be restorative through four components: 'being away', 'extent', 'fascination', and 'compatibility'. Secondly, SRT posits natural spaces as being spaces where recovery from stressful situations can occur. A positive change to emotional state occurs as well as physiological recovery in relation to the parasympathetic nervous system.

When exploring the mental well-being benefits which can be gained from exposure to UGS, experimental studies are often utilised to investigate these effects as they allow for control and manipulation of stimuli to help isolate particular UGS characteristics that may promote greater benefit. A dominant number of experimental studies investigating the mental well-being benefits of UGS involve exposure to environments which are free of people. This is problematic for ecological validity as visits to greenspaces are often not in solitude and other people are usually present in the space (Yen & Syme, 1999). This was especially noticeable during the COVID-19 pandemic which saw over-crowding in local parks and other greenspaces (Burnett et al., 2022).

Moreover, research demonstrates that one of the pathways between UGS and improved well-being is via social interaction which promotes social cohesion and reduced loneliness (Astell-Burt et al., 2022; Hartig et al., 2014; Roe & McCay, 2021). Research also supports social cohesion and loneliness as mediators of the relationship between greenspace and mental well-being (van den Berg et al., 2019). Moreover, it is consistently reported that social contact in UGS is positively associated with improved health and well-being and quality of life (Bonsang & van Soest, 2012; Sugiyama & Ward Thompson, 2005). Qualitative research in this thesis extends these quantitative findings

by revealing that the social aspects of UGS and sharing the space with other users is an important factor for shaping mental well-being across multiple age groups (Chapter 3; Reece et al., 2024). However, limited experimental research has focused on the impacts of having people present in a space might have on mental well-being, restorativeness, and feelings of social connectedness.

When discussing the potential social benefits of exposure to UGS, other factors can also be influential, such as age. For example, in a study involving older adults, it was concluded that greenspaces supported social contacts in the neighbourhood (Kemperman & Timmermans, 2014). And for young adults, UGS can be spaces for socialising with friends (Jennings & Bamkole, 2019; Lyons et al., 2022). It is therefore essential that research studies consider how age might influence the impact of social dimensions of UGS experiences on mental well-being, restorativeness, and social connectedness.

People have been considered in urban spaces and whether crowdedness (many, few pedestrians) influences attention, although there is a lack of supporting evidence (Ulrich et al., 1991). Whilst literature is limited, some studies to an extent have considered people being present in UGS. One study used a questionnaire and EEG as measures to assess the emotional impact of crowding perception on users of small UGS in China (Zhang et al., 2023). Their main finding was that crowding can invoke negative emotions of users of these spaces, but how attractive a space is can moderate this effect. Cross-sectional surveys have also found that in relation to recreational use, UGS are preferred when visitor numbers are lower (Arnberger, 2012), and similarly low use levels are preferred when individuals are seeking stress relief in a space (Arnberger & Eder, 2015). Another study used choice-based conjoint analysis to explore the importance of components in an urban park (Nordh et al., 2011). Via a questionnaire, adult residents in Norway were asked about their preferences towards various components including the number of other people in the park (no people, few people, many people). They concluded that a few other people being present in the park was preferred over no people and many people. Whilst the method reached a wide audience, this study reported participants' preferences, which do not necessarily equal mental well-being outcomes. Building on this study, visual stimuli have been used. One prominent paper, combining three experimental studies, looked at the effect of people in natural and urban settings (Neale et al., 2021). They used a combination of stimuli including moving and static images, and videos, and measured psychological restoration and social well-being. Participants viewed different environments with varying numbers of people

present. Across all three studies, viewing nature scenes had a positive effect on mental well-being outcomes. Two of their studies tested the effect of people being in nature scenes and found that there were no significant differences on the outcome measures between the scenes that had people and the scenes that had no people. This study was an initial start to focusing on the presence of people, paving the way for future work to look at other factors such as crowding and the influence of individual differences such as age.

It is important to define crowding here as crowding and density of people can be defined differently. Density refers to the number of people in a space, e.g., number per square meter, and can be seen as a more objective measure. Whereas crowding is subjective and defined as, “a negative psychological state that results from perceiving that there are too many people present in the available space” (Lepore, 2012). This study focuses on subjective crowding and feeling like an UGS has too many people in it. It is further defined by Stokols (1972) as, “when the need for space exceeds the current supply – a person’s subjective experience”. It is important to further research the effect that people being in present in a space can have on mental well-being and its perceived restorativeness. However, implementing a naturalistic study which allows for isolation of the effect of the number of people present has challenges. Controlling for the amount of people being present in a space at different times could be possible through actors, although there would be other factors outside of experimental control, for example extraneous variables including the weather, noise levels, and the amount of wildlife present. One study has used confederates to manipulate the amount of people present and reported that an increased number of people in the greenspace resulted in lower mood and affective responses, especially among women (Honey-Rosés & Zapata, 2023). A limitation of this study was that it employed a between-subjects design where participants either took part in the treatment (greenspace with people) or control condition (greenspace without people). Isolating the effect of people being present in the greenspace and drawing conclusions is difficult due to influence of participant variability between conditions.

Moreover, one way in which to provide an immersive setting, control for extraneous variables and isolate an effect of interest, is through using new research tools such as VR. By using VR, the components that are present (visually and audibly) in an environment can be fully controlled (Abella et al., 2020). They also looked specifically at trust and willingness to interact with other people and perceptions towards people of a different

gender and ethnicity. Participants (N = 2000) were assigned to 1 of 4 groups which viewed a VR UGS for two and half minutes. The park was altered across levels by adding additional components including urban design elements (e.g., benches, streetlamps), people (from diverse groups), or both. The park with no added elements acted as the control condition. Adding design elements led to more willingness to use the space, however it was not associated with social cohesion. Increasing the diversity of park users did not increase the willingness to use the space or have a consistent effect on social cohesion.

6.3.1 Summary of literature and present study

Overall, it is clear that UGS are a social experience (Dinnie et al., 2013) and can have social benefits (Clarke et al., 2023; Nordh et al., 2011; van den Berg et al., 2019), however the effects of differing numbers of people being present and subjective crowding have rarely been experimentally tested. Previous studies also support the need for more research to investigate social connectedness and relations in greenspace (Dinnie et al., 2013). This study aimed to address these gaps. The purpose of the present study was to experimentally test whether subjective crowding in an UGS has an impact on the psychophysiological indicators of mental well-being, perceived restorativeness, and feelings of state (rather than trait) social connectedness. A secondary exploratory aim was also to investigate whether age has a modifying effect on these outcomes.

Research questions

RQ1: What effect does crowdedness in an urban greenspace have on psychophysiological indicators of mental well-being?

RQ2: To what extent does crowdedness impact the perceived restorative experience of urban greenspace exposure?

RQ3: What effect does crowdedness have on feelings of social connectedness in an urban greenspace?

RQ4: Are RQ1, RQ2 and RQ3 impacted by age?

6.4. Methods

6.4.1. Participants

The aim of this study was to recruit participants who are from a broader spectrum of the general population than typical experimental psychological studies. Numerous studies

have recruited from specific populations, such as students or academics (Druckman et al., 2011), which are not representative of the general population and are often recruited due to their accessibility (Hanel & Vione, 2016). By recruiting non-academic staff working at a university, this study helps to fill this gap and provides more generalisable knowledge and findings to the field. Non-academic staff would be more representative of the general population due to their diverse job roles and levels of education.

This study also considered age effects and aimed to compare young adults (18-24 yrs) with adults (25 yrs +). The threshold for age of young adults (24 yrs) was based on cut-offs used in organisations such as the NHS, ONS and WHO (NHS, 2024a; Office for National Statistics, 2020; World Health Organization, 2024b) and previous literature (Bray et al., 2022).

To determine the sample size needed to allow for the comparison between two age groups and have the power to find an effect, a power calculation was conducted using G*Power 3.1. The effect size was set at 0.3 and the power was 0.8. The parameters for this calculation were informed by the previous pilot study (Chapter 5) and the differences between environmental condition found in relation to the UWIST MACL measure for mental well-being. This study aimed to recruit a total of 62 participants including both young adults (n = 31) and adults (n = 31). The final sample size totalled 58 participants.

6.4.2. Recruitment

Recruitment occurred between May and July 2024. The study aimed to recruit people from a broader spectrum of the general population than typical experimental psychological studies. An opportunistic approach was taken, with the initial advert directed towards staff working within professional services at the University of the West of England (UWE). This included departments such as estates and facilities, IT services, research business and Innovation, library services, film marketing, student union, planning and business intelligence, student outreach, doctoral academy, Bristol robotics lab, strategic programmes office, human resources, careers service etc. This meant that the sample would not predominantly consist of academic staff or the student population which studies often use (Druckman et al., 2011). This strategy allowed for quick and accessible recruitment, i.e., the study was convenient for the participants as they already work on campus.

Several avenues of recruitment were implemented. These included physical poster advertisement around the university campus, advertisement through the university staff and student community page (Yammer) where there are 19,000+ members, social media (LinkedIn, X), and word of mouth. Interested participants either signed up through email contact or directly chose a timeslot using a QR code on the poster linked to a *Doodle Poll* schedule. A participant information sheet was also provided when participants signed up (through email or *Doodle Poll*). Participants then arrived at the study room where they considered their participation and provided consent to take part. All participants who arrived to take part signed consent and took part. A £10 voucher for LovetoShop was given to each participant to thank them for their time in taking part. No participants dropped out or withdrew their data.

There were eligibility criteria for taking part in the study. These included not having a chronic disease of the heart (e.g. pacemaker) and not having high blood pressure. This was due to the physiological measures which were recorded during the experiment (heart rate, blood pressure) and not wanting these to be influenced by pre-existing medical conditions. The adopted threshold for high blood pressure was 140/90mmHg (NHS, 2023). Due to the visual nature of VR, participants were also required to have normal or normal-to-corrected vision. The fit of the headset was adjustable and allowed for glasses or no glasses to be worn whilst wearing it. Finally, participants were excluded if they suffered severely from motion sickness as this is a common side effect with the use of VR (Oh & Son, 2022).

During recruitment, it became clear that it would be difficult to reach the planned sample sizes required to conduct a comparison between the two age groups (young adults and adults). Therefore, the recruitment strategy was adapted so that students and academics were eligible to take part, with the aim of recruiting more young adults.

6.4.3. Experimental design

This study adopts a within-subjects (repeated measures) design whereby all participants took part in all experimental conditions and therefore act as their own comparators (Charness et al., 2012). The experiment comprised of viewing stimuli, completing a questionnaire of subjective measures, physiological measures, and a qualitative interview. The independent variables for this study were: (a) the VR environment viewed (three levels: no people, few people, lots of people), and (b) the timepoint that measures were administered at (two levels: after administration of a stressor and before viewing

the VR environment, and after viewing the VR environment), in order to allow for assessment of the potential for each environment to improve psychophysiological indicators of mental well-being, perceived restorativeness, or social connectedness. This study therefore employed a 3 x 2 repeated measures design with the principal interest being in the analysis of the main effect of timepoint (to assess the benefits of all three environments collectively) and the interaction between environment and timepoint (to assess whether each environment improved outcomes to differing extents).

A within-subjects design was chosen due to the advantage of having more statistical power than between-subjects, as well as requiring smaller sample sizes which suited the time constraints and scope of this study (Charness et al., 2012). However, one challenge with a within-subjects design experiment is the chance of order effects. Participants may start to learn the procedure of the experiment and answer in a socially desirable way (demand effect), have fatigue or boredom nearer the end of the experiment, or experience carry over effects from the previous stimuli. To avoid this, breaks were provided in between stimuli exposure and participants were able to have a break at any time to avoid fatigue and eye strain. The order in which the VR environments were viewed was also counterbalanced across participants so to avoid any order effects which might occur. It was first determined that there were six sequences in which participants could view the VR environments (Table 6.1). The sequence for each participant was then randomly assigned using a random number generator in Microsoft Excel.

	Stimuli 1	Stimuli 2	Stimuli 3
Sequence A (n = 9)	No people	Few people	Lots of people
Sequence B (n = 9)	No people	Lots of people	Few people
Sequence C (n = 11)	Few people	Lots of people	No people
Sequence D (n = 10)	Few people	No people	Lots of people
Sequence E (n = 11)	Lots of people	No people	Few people
Sequence F (n = 8)	Lots of people	Few people	No people

Table 6.1. Counterbalanced sequence order of VR stimuli.

6.4.4. Stimuli

Prior to viewing each VR environment, the study included a stressor task which involved watching a 2-minute video of loud, heavy motorway traffic on a flat-screen computer (Figure 6.1). This was to induce a negative state so that the experiment could test for restorative effects, which is a procedure previous studies have employed (Hedblom et

al., 2019; Wang et al., 2016; Yin et al., 2022). In total, participants watched 3 x 2 minute traffic videos, one before each VR environment. One traffic video was used from YouTube and the video was then segmented into 3 x 2 minute chunks which were highly similar to each other and therefore were shown in the same order for all participants. This was the same stressor used in the previous pilot studies (Chapters 4 and 5).



Figure 6.1. Still image from the video used as a stressor manipulation in the present study.

Creation of the VR environments took roughly two months (Spring 2024) and was conducted in the Digital Gallery (Engineering building) on Frenchay campus at the University of the West of England. The environments were built on *Unity* (Unity Technologies, 2024) from scratch but using pre-built paid ‘assets’ which were acquired from the *Unity Asset Store*. For example, individual components such as trees, benches, and lampposts can be downloaded and used to compile into an environment. Whilst this is an efficient way of building an environment, it limits the type of components which can be used as you are limited to whatever is available at the time on the *Asset Store*. Careful decision making was conducted when choosing components which were as realistic as possible, what was available and affordable, and suited what was needed for the stimuli.

The VR environment created was a 360-degree experience and involved both visual and audio elements which participants would experience for 5 mins (per stimuli). The VR HMD used was the Meta Quest 2 (Meta, 2022). The Meta Quest 2 was chosen as the HMD due to its good graphics and resolution, affordability and availability, as well as its compatibility with Unity. It was possible to create the environment in Unity (on a PC) and then transfer them to the headset. The VR environment was also a stationary experience, i.e., participants could not walk or move about in the space. The aim was to build an environment which resembled an UGS in the UK. This would then be used in all

three stimuli exposures and only varied in terms of the number of people in the greenspace, in order to isolate the effect of different levels of crowding. The environments were designed by creating 3 levels of subjective crowding. Environment 3 (with lots of people) was designed to feel crowded but was not created based on density metrics. Similarly for Environment 2 (a few people), where some people are presented so to make the space feel not too crowded. These levels were piloted to ensure that the busiest environment did feel crowded, but it is recognised that this is a subjective response. The design decisions for the UGS and the restorative properties included in it were supported by previous literature (Table 6.2).

Properties incorporated in the VR UGS	Support from previous research
Vegetation (grasses, trees, bushes)	(Nordh, 2010; Nordh et al., 2009)
Water feature (fountain)	(Nordh & Østby, 2013)
Seating (benches)	(Nordh, 2012)
Lighting (lamp posts)	(Zhao & Huang, 2021)
Pathways	(Lai et al., 2020)

Table 6.2. Supportive research for the properties incorporated into the VR UGS.

After the ‘baseline’ UGS had been designed with **no people** in it (Figure 6.2), two variants of the space were created. The first variant had a **few people** added to the environment, distributed evenly across age (e.g., 3 children, 3 young adults, 3 adults, 3 older adults), gender and ethnicity (even amounts of men and women and white and non-white people) (Figure 6.3). This decision was made so that the characteristics of the people in the UGS should not influence their perception of the environment and the results. Lastly, the second variant included the same people who were present in the first variant, but with **lots of people** added into the scene (Figure 6.4). Similarly to the first variant, the people varied evenly in terms of their age, gender and ethnicity. The people (designs) used in the VR environments were sourced from a creator (Denys Almaral) through *Sketchfab* (FBX files).

This decision to choose designs from *Sketchfab* was due to the lack of available assets of realistic looking people on the *Unity Asset Store*. The people are 3D, static and vary in terms of colours of clothing and poses. The decision was made to make the people static, without movement, due to the level of complexity that movement would have required and was also not necessary for answering the research questions. The

movement of people was not a focus of this study but would be an interesting avenue for future designs and research. We henceforth refer to these three environments as ‘no people’, ‘few people’ and ‘lots of people’ respectively.



Figure 6.2. Screenshots of the environment where no people are present in the UGS.



Figure 6.3. Screenshots of the environment where a few people are present in the UGS.



Figure 6.4. Screenshots of the environment where lots of people are present in the UGS.

In order for the VR environments to feel more immersive and representative of the environment being viewed, more than one sense was incorporated. Visual and audio stimuli were used due to their low-cost implementation and research which suggests

that visual and auditory information can reinforce one another or exhibit interference (Deng et al., 2020; Song et al., 2018). Finding pre-made audio which matched each visual environment whilst also staying controlled across environments with the sounds of the people and type of birdsong was not possible and could have led to the audio being an extraneous variable which influenced the results. Therefore, the decision was made to find individual components of audio (traffic, birdsong, chatter) which reflected characteristics of the environments, and combine each into a bespoke track for each environment which matched the amount of people that were visible. Audio files were sourced from BBC Sound Effects (BBC, 2024) and then combined and mixed using *Audacity* (Audacity Team, 2014). Audio files were 5 minutes long to match the length of time which each VR environment was viewed for. For all VR environments, audio included continuous birdsong of species common to the UK (blackbirds, pigeons, wrens) and the intermittent sound of distant traffic. For the environment with a few people in, birdsong and traffic stayed consistent but audio of brief chatter was added. People of different ages can be heard talking, laughing and shouting. This faded in and out intermittently to reflect only a few people being present in the UGS. For the environment with lots of people in, the sounds of people were more constant, to reflect a busier and noisier space where lots of people are present. This was achieved by adding layers to the audio already created for the environment with few people in.

6.4.5. Measures

The questionnaire consisted of three parts ([Appendix 24](#)). Before viewing any stimuli, there were baseline measurements which included trait measures reflecting personality characteristics which were deemed important to control for in analysis. Participants were also asked if they had ever used VR before. Secondly, there were the measures of the main outcomes; mental well-being, perceived restorativeness, and social connectedness, typically administered after the stressor but before viewing stimuli, and after viewing the stimuli. Thirdly, the final part of the questionnaire consisted of demographic and socio-economic measures.

6.4.5.1. Baseline questionnaire / trait measures

Loneliness

Trait loneliness was measured at the beginning of the experiment, before participants viewed any of the VR environments. This was included, and controlled for as a covariate,

due to the potential it could have in confounding the relationship between the environments and the outcomes. Loneliness was measured using The Revised UCLA Loneliness Scale which consisted of 20 items and measures how often people experience a sense of social isolation (Russell et al., 1980) (Table 6.3). The scale was developed within the Social Psychology discipline but is now also used, in various versions, within Environmental Psychology studies (Neale et al., 2021).

Participants are required to indicate how often they feel the way described in the statements. Responses are on a 4-point Likert scale (1 = 'never', 2 = 'rarely', 3 = 'sometimes', 4 = 'often'). A total score for loneliness is the sum of all 20 items, with a range between 20 and 80. A higher score indicates an increased feeling of loneliness. Half of the items reflect satisfaction with social relationships and half reflect dissatisfaction. Items reflecting satisfaction and which are positively worded (1, 4, 5, 6, 9, 10, 15, 16, 19, 20) were reversed before scoring. The internal consistency of the scale is reported elsewhere to be high ($\alpha = .96$) (Russell et al., 1980).

Item no.	Statement
1	I feel in tune with the people around me
2	I lack companionship
3	There is no one I can turn to
4	I do not feel alone
5	I feel part of a group of friends
6	I have a lot in common with the people around me
7	I am no longer close to anyone
8	My interests and ideas are not shared by those around me
9	I am an outgoing person
10	There are people I feel close to
11	I feel left out
12	My social relationships are superficial
13	No one really knows me well
14	I feel isolated from others
15	I can find companionship when I want it
16	There are people who really understand me
17	I am unhappy being so withdrawn
18	People are around me but not with me
19	There are people I can talk to
20	There are people I can turn to

Table 6.3. Items in the Revised UCLA Loneliness Scale.

Trait social connectedness

As with loneliness, a measure for trait social connectedness was included to control for as a covariate. Trait social connectedness was measured using The Social Connectedness Scale Revised (SCS-R) (Lee et al., 2001). The scale consists of 20 items of which 10 are positively worded statements and 10 are negatively worded (Table 6.4). Participants rate on a 6-point Likert scale the degree to which they agree or disagree with each of the statements, 1 = 'strongly disagree' to 6 = 'strongly agree'.

Items negatively worded (1, 2, 3, 4, 5, 6, 8, 10, 15, 18) are reversed before scoring. A total score for trait social connectedness is the sum of all 20 items, ranging between 20 and 120. A higher score for the SCS-R indicates a stronger sense of trait social connectedness. This scale also has high internal consistency ($\alpha = .95$) (Lee et al., 2001).

Item no.	Statement
1	I feel distant from people
2	I don't feel related to most people
3	I feel like an outsider
4	I see myself as a loner
5	I feel disconnected from the world around me
6	I don't feel I participate with anyone or any group
7	I feel close to people
8	Even around people I know, I don't feel that I really belong
9	I am able to relate to my peers
10	I catch myself losing a sense of connectedness with society
11	I am able to connect with other people
12	I feel understood by the people I know
13	I see people as friendly and approachable
14	I fit in well in new situations
15	I have little sense of togetherness with my peers
16	My friends feel like family
17	I find myself actively involved in people's lives
18	Even among my friends, there is no sense of brother-sisterhood
19	I am in tune with the world
20	I feel comfortable in the presence of strangers

Table 6.4. Items in the Social Connectedness Scale-Revised.

Connectedness to nature

A final trait measure included in the baseline questionnaire, and controlled for as a covariate, was a measure for connectedness to nature, which was measured using the Connectedness to Nature Scale (CNS) (Mayer & Frantz, 2004). The scale consists of 14 items and is rated on a 5-point Likert scale, 1 = 'strongly disagree' to 5 = 'strongly agree' (Table 6.5). Participants are asked to answer the questions in terms of *the way you generally feel*. Items 4, 12 and 14 are negatively worded and are reverse scored. An average score for connectedness to nature is then calculated from all 14 items. A higher score indicates feeling more strongly connected to nature. The scale has also been demonstrated to have high internal consistency ($\alpha = .84$) (Mayer & Frantz, 2004). The CNS is a robust scale to use as it has been found to be invariant across numerous ages and genders worldwide (Swami et al., 2024).

Item no.	Statement
1	I often feel a sense of oneness with the natural world around me
2	I think of the natural world as a community to which I belong
3	I recognize and appreciate the intelligence of other living organisms
4	I often feel disconnected from nature
5	When I think of my life, I imagine myself to be part of a larger cyclical process of living
6	I often feel a kinship with animals and plants
7	I feel as though I belong to the Earth as equally as it belongs to me
8	I have a deep understanding of how my actions affect the natural world
9	I often feel part of the web of life
10	I feel that all inhabitants of Earth, human, and nonhuman, share a common 'life force'
11	Like a tree can be part of a forest, I feel embedded within the broader natural world
12	When I think of my place on Earth, I consider myself to be a top member of a hierarchy that exists in nature
13	I often feel like I am only a small part of the natural world around me, and that I am no more important than the grass on the ground or the birds in the trees
14	My personal welfare is independent of the welfare of the natural world

Table 6.5. Items in the Connectedness to Nature Scale (CNS).

6.4.5.2. Psychological outcome measures

Mental well-being

Mental well-being was assessed using a measure of non-clinical mood: a shortened version of the University of Wales Institute of Technology Mood Adjective Check List (UWIST MACL) (Matthews et al., 1990). This scale has been used in previous environmental research measuring mental well-being and perceived restorativeness in relation to urban nature (Roe et al., 2019). The scale consists of 12 items and measures three dimensions: hedonic tone (pleasant/unpleasantness), stress (tense arousal) and energy. There are four items for each of the three dimensions. For hedonic tone, items include 'happy', 'content', 'sad', 'sorry', whereby scores for 'sad' and 'sorry' are reversed. For stress, items include 'nervous', 'tense', 'relaxed', 'calm', whereby scores for 'relaxed' and 'calm' are reversed. And for energy, items include 'active', 'energetic', 'passive', 'sluggish', whereby scores for 'passive' and 'sluggish' are reversed. For each item, participants respond on a 4-point Likert scale (1 = 'definitely not', 2 = 'not much', 3 = 'quite', 4 = 'definitely') in regard to how they feel about that item. Participants completed this measure after viewing each stressor video and each VR environment.

Perceived restorativeness

Perceived likelihood of restoration was measured using the Perceived Restorativeness Scale (PRS) short version (Berto, 2005). This scale is based on the original PRS which contains 29 items and measures perceptions of five restorative components: being-away, fascination, coherence, scope, and compatibility (Korpela & Hartig, 1996). For the PRS short version, one item is used to measure each of the five components (Table 6.6).

Participants are asked, 'We are interested in how you experience the environment you have just seen. To help us understand your experience, we have provided the following statements for you to respond to. Please read each statement carefully, and then indicate on the scale the extent to which the given statement fits your experience of the environment you have just seen'. The statements are rated on an 11-point scale (0 = not at all, 10 = completely). The mean across the five items is used to create a score for perceived likeliness of restoration (range = 0-10). The PRS short version is a reliable tool and has a Cronbach's alpha value of ($\alpha = .79$) (Berto, 2005).

Item no.	Restorative component	Statement
1	Being-away	That is a place which is away from everyday demands and where I would be able to relax and think about what interests me
2	Fascination	That place is fascinating; it is large enough for me to discover and be curious about things
3	Coherence	That is a place where the activities and the items are ordered and organized
4	Scope	That is a place which is very large, with no restrictions to movements; it is a world of its own
5	Compatibility	In that place, it is easy to orient and move around so that I could do what I like

Table 6.6. Items in the PRS short version.

State social connectedness

State social connectedness was also measured after participants viewed each of the VR environments using the UBC State Social Connection Scale (UBC-SSCS) (Lok & Dunn, 2023). This is the first psychological scale which has been developed to measure state social connectedness. Compared to the trait measure for social connectedness, which is expected to remain relatively stable over time, a person's state level of social connection may change following brief social interaction (Lok & Dunn, 2023). This measure was completed after viewing each of the VR environments (which included varying amounts of people).

Item no.	Statement
1	I would feel distant from people
2	I would not feel related to most people
3	I would feel like an outsider
4	I would feel like I would be able to connect with other people
5	I would feel disconnected from the world around me
6	I would feel close to people
7	I would see people as friendly and approachable
8	I would feel accepted by others
9	I would feel like I had a sense of belonging
10	I would feel a strong bond with other people

Table 6.7. Items used to measure state social connectedness, adapted from the UBC-SSCS.

The UBC-SSCS consists of 10 items whereby participants are required to indicate on a 7point Likert scale the extent to which they agreed or disagreed with each statement (1 = strongly disagree, 4 = neither agree nor disagree, 7 = strongly agree). The internal consistency for the scale is high ($\alpha = .90$) (Lok & Dunn, 2023). The question asked participants, 'Please think about how you felt viewing the environment you have just seen.

To what extent do each of the following statements describe how you felt?'. For this study, the statements were re-worded into conditional tense due to the nature of VR and the people not being physically present. For example, statements such as 'I felt distant from people' were re-worded to 'I *would* feel distant from people' (Table 6.7), because it would be unrealistic for participants to respond to 'I felt distant from people' in a virtual space.

Items 1, 2, 3, and 5, which are negatively worded, were reverse scored. An overall score for state social connectedness is the total of all 10 items, and ranges from 10 to 70, with a higher score indicting a stronger feeling of social connectedness.

Demographic and socio-economic measures

At the end of the questionnaire and after all stimuli had been viewed, participants were required to answer several demographic and socio-economic questions. Open-ended text boxes were provided so that participants could indicate their age, gender and ethnicity. The free text boxes gave participants the freedom to describe their demographics with what they felt was appropriate for them, hence providing a more inclusive option. Additionally, participants were asked to describe their household type and choose the most appropriate description: couple with dependent children, lone parent with dependent children, nonretired couple with no dependent children, one non-retired person, one retired person, retired couple with no dependent children, other multi-person household (Department for Levelling Up, Housing and Communities, 2023). Household type was controlled for due to the confounding influence it may have on feelings of social connectedness. Living alone, with other people, or with children may impact how socially connected or lonely people feel which could influence the results of this experiment.

6.4.5.3. Physiological outcome measures

As demonstrated in previous research (Chapters 4 and 5), psychological and physiological measures do not always align in their conclusions (Reece, Bornioli, Bray, & Alford, 2022; Reece, Bornioli, Bray, Newbutt, et al., 2022). Similarly to the research conducted in Chapter 5, this study included psychological, physiological and qualitative measures. The objective measures adopted in this study were heart rate and blood pressure. These have both been used as reliable physiological measures of mental well-being and stress (Allen et al., 2014; Chu et al., 2024).

To measure heart rate and blood pressure, initially, a blood pressure monitor upper arm cuff was used, which had an adjustable cuff, LCD display, and pulse rate monitor (GetFit, 2024).

Heart rate measured by beats per minute (bpm) was recorded after each time the participants viewed the stressor and the VR environments. Blood pressure was recorded with systolic and diastolic pressure, measured in millimetres of mercury (mmHg). The adopted threshold for high blood pressure, and therefore an exclusionary criterion for the study, was 140/90mmHg (NHS, 2024b). Two individuals emailed with interest in taking part in the experiment but were excluded due to them stating that they had high blood pressure.

Both heart rate and blood pressure were measured using a wrist cuff which measures in real time and is placed on the left wrist. Participants were asked to relax their arm and breathe normally whilst the recordings were taken. There was sufficient time between participants arriving for the experiment and the first physiological recordings such that these recordings were 'resting' measures.

6.4.5.4. Qualitative measures

At the end of the experiment, a brief semi-structured interview was conducted in order to gather more detail and context to the participants' subjective and objective quantitative outcomes. One of the main findings from the previous pilot study (Chapter 5) was the importance of using multiple measures and triangulating results from psychological, physiological, and qualitative measures. Because of this, and unlike the pilot study, the qualitative questions were mandatory in this study. Seven open-ended questions were asked and focused solely on the VR aspect of the experiment ([Appendix 25](#)). Questions included, 'How was the experience of viewing the VR environments?', 'Is there anything in particular that attracted your attention in the videos, and why?', 'What are your thoughts around the people that were present in the environments?', 'Which

environments did you prefer to be in and why?', 'To what extent did you feel like you were really there in the environments?', 'Do you have any comments on the quality of the technology and did you identify any technical issues?', and 'Do you have any additional comments?'. Responses were audio-recorded and transcribed into Microsoft Word. A KINPEE digital audio recorder was used to record the interviews (KINPEE, 2022). Transcripts were anonymised with participant names replaced with pseudonyms for the purpose of reporting the findings (e.g., quotes). Once transcription was complete, audio recordings were destroyed.

6.4.6. Procedure

Participants initially interested in taking part in the study were provided with a participant information sheet (via *Doodle Poll* or email) which outlined the full details and intentions of the research ([Appendix 23](#)). Once a timeslot was confirmed, participants arrived at the study room (a small meeting room on Frenchay campus at UWE Bristol) and provided written informed consent in order to take part ([Appendix 22](#)). The procedure of the experiment was also verbally described and there was an opportunity for participants to ask any questions. This was not only an ethical requirement of the study but also aided in building rapport with the participants. Building rapport was important as it would allow the participant to feel more comfortable and encourage openness and honesty for the qualitative stage of the experiment. Participants were provided with a random participant number so that their data could be recorded anonymously. Participants were seated on a swivel chair and were able to view the 360-degree VR environments whilst seated. A laptop on the desk was placed in front of participants which displayed the questionnaire and stressor task (traffic videos).

Before viewing any stimuli (stressor or VR), participants were first required to complete a baseline questionnaire (using Qualtrics) which asked participants if they had ever used VR before, as well as complete baseline measurements (trait measures). Participants then completed the stimuli phase of the experiment (Figure 6.5) followed by a final questionnaire which comprised of demographic and socio-economic questions. Lastly, participants completed the qualitative phase of the study before being thanked and debriefed. The total duration for the study was approximately 1 hour. No participants stopped the study early or withdrew their data.

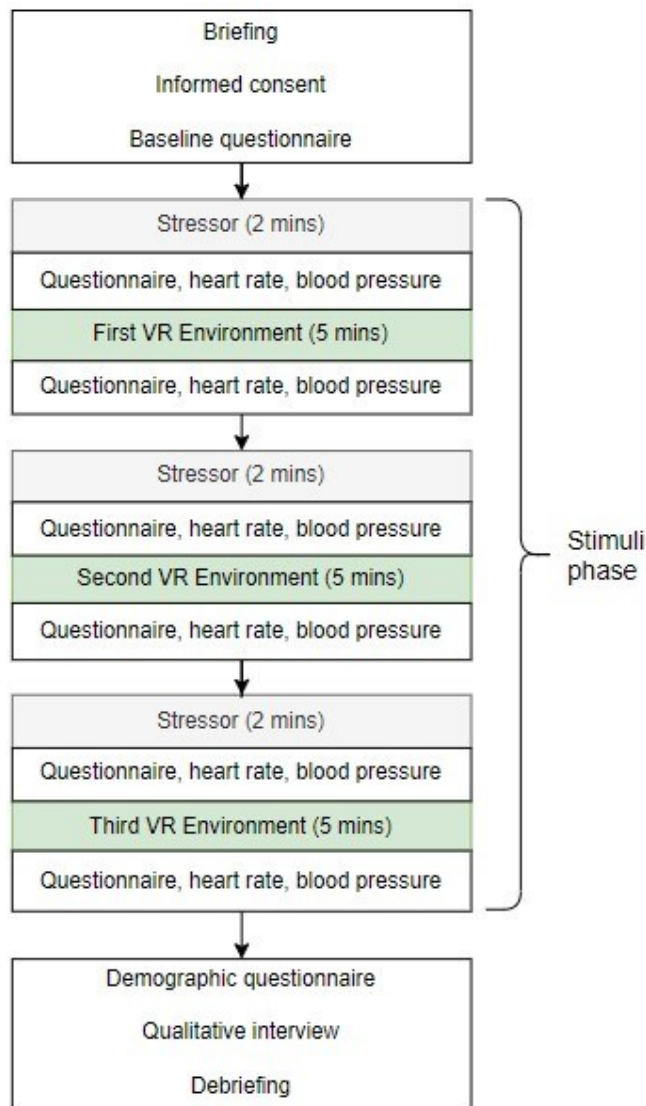


Figure 6.5. Experimental procedure.

6.4.7. Ethical considerations

Ethical approval was provided by the Faculty Research Ethics Committee (FREC) from the University of the West of England in accordance with the declaration of Helsinki (UWE REC REF No: CHSS.23.11.065) (see [Appendix 21](#)). All data collected were confidential and anonymised so participants were not personally identifiable. Voice recordings from the qualitative data collection were securely destroyed after anonymous transcription. The anonymised data were securely stored on OneDrive which only the researcher and supervisory team had access to. It was also made clear to participants that they could stop the experiment at any time and without providing a reason. Participants were also able to withdraw their data from the study up to 1 week after participating. Data management

was in line with the University's requirements, Data Protection Act 2018 and General Data Protection Regulation requirements.

A full risk assessment was also completed and approved prior to data collection. The main risk for participating in this experiment was motion/cybersickness induced by VR which can include side effects such as eye strain, headaches, feeling dizzy, and nausea (Oh & Son, 2022). To reduce these possible effects, participants experienced the VR environments whilst sat down and only wore the headset for a short duration (5 minutes) at any one time. Additionally, participants were allowed breaks in between viewing each environment and they were asked how they felt after each viewing, and whether they were experiencing any effects of cybersickness. At the beginning of the experiment, participants were also asked if they had used VR before, and if so, whether they had experienced any side effects before.

6.4.8. Data analysis

Quantitative analysis

All quantitative analyses were conducted using IBM SPSS Version 29 (IBM Corp., Armonk, NY, USA). Quantitative data was analysed using linear mixed-effects models which allow for fixed and random effects to be considered. For this study, the fixed effects are the environment, timepoint, the interaction between environment and timepoint, and all of the covariates. Whereas the only random effect is the participant. This model is statistically equivalent to a repeated measures ANOVA as both can account for within-subject variability across two independent variables. Eight models were run, one for each outcome (dependent variable): well-being – stress, mental well-being – hedonic tone, well-being – energy, perceived restorativeness, state social connectedness, resting heart rate, and resting systolic and diastolic blood pressure. Dependent variables were regressed on the interaction between timepoint (post stressor/pre-VR environment and post-VR environment) and environment condition (no people, few people, lots of people). All dependent variables were treated as continuous variables. Each model also included potential confounders: age, gender, ethnicity, household type, baseline stress, baseline hedonic tone, baseline energy, loneliness, trait social connectedness, and connectedness to nature. While most dependent variables could be credibly attributed to both the stressor video and VR environments, the exception was state social connectedness, i.e. it would be difficult for a participant to authentically report how connected they felt with other people after the stressor video containing scenes of traffic. For this reason, state social connectedness was only measured at the second

timepoint (post-VR environment) and for this outcome variable, interest was accordingly in the main effect of environment only.

Age was firstly explored as a covariate in the study and treated as a continuous variable. Gender, ethnicity and household type were treated as nominal/categorical variables in the linear mixed-effects models (LMMs). Gender was grouped into men and women whereby women were treated as the reference category. Ethnicity was recorded initially as free text and then categorised according to the five high-level ethnic groupings advised by the ONS (Office for National Statistics, 2022), and further dichotomised into White (reference category) and non-White ethnicities here due to low sample sizes in non-White ethnic groupings. Similarly, household type was operationalised in three categories to allow for appropriately powerful analyses: couples with children (reference), couples without children and other household type.

A further exploratory investigation into age was conducted by dividing the dataset into two groups to compare younger and older participants in the sample. The data was divided based on the median age of participants (37 years old) and so that two similar sized groups could be compared which have enough statistical power. LMMs as described above were repeated for each age group separately as an exploratory sensitivity analysis which resulted in a further 16 LMMs. It is recognised that this number of models can increase Type 1 errors, however, were still conducted due to the exploratory nature of this investigation.

Additional exploratory analysis was conducted focusing on the individual components of the PRS. As this was not the focus of this study, and more of an exploratory analysis for further research to potentially continue, the results and output are presented in [Appendix 28](#).

Qualitative analysis

The framework method is a systematic and flexible method used to manage and analyse qualitative data (Gale et al., 2013; Ritchie & Spencer, 1994). The method is a popular choice of analysis in multi-disciplinary research, including applied, health, and social science research (Gale et al., 2013; Goldsmith, 2021; Parkinson et al., 2016). The main feature of the framework method is the creation of a matrix output where the data is charted into rows (cases) and columns (themes). The framework method is suitable for analysing interview data and generating themes whereby comparisons can then be made between and within cases and themes. The seven steps for the framework method,

outlined by Gale et al., (2013), include: transcription, familiarisation with the interview, coding, developing a working analytical framework, applying the analytical framework, charting data into the framework matrix, and interpreting the data.

The first step involves transcribing the audio recordings verbatim. Transcription transforms the data into a useable format (written) and allows the researcher to become immersed in the data. The second step of familiarisation involves listening back to the audio recordings and reading and reviewing transcripts and any notes made during the interviews. After familiarisation, coding is then completed (via NVivo) which involved inductive, or 'open coding', for this study. This meant that all relevant data was coded regardless of previous theories or any pre-defined areas of interest. After the first few transcripts are coded, codes are grouped together into categories (initial themes) to form a working analytical framework. The next step involves using the initial codes and categories to code and categorise the remaining transcripts. After, a matrix is created in Microsoft Excel and the data is charted into the matrix (see [Appendix 27](#)). The final stage of the framework method involves interpreting and mapping the data which can include clarification of concepts, identifying patterns and relationships, developing explanations, and generally recognising key characteristics of the data which define it as a whole.

6.4.9. Piloting the experiment

Before main recruitment commenced, piloting of the experiment was conducted. This was done to test the feasibility of the study and trial the experimental procedure (e.g. to determine the length of the experiment). It also allowed for testing of the questionnaire to see if the questions were understandable, how user friendly the online questionnaire was, as well as the length of it in regard to potential fatigue and boredom. Additionally, piloting allowed for a trial of the VR headset and the technicalities that come with navigating participants through a virtual world (e.g., using the controller to navigate in and out of the UGS's).

The piloting phase involved conducting the planned experiment with a smaller sample (N = 8). The majority (87.5%) of pilot participants were doctoral students at the university. Both males and females participated and ranged in age from 27 to 45 years old. They were diverse in ethnicity (Black-African, Turkish, White, White British) and household type (couple with dependent children, one non-retired person, non-retired couple with no dependent children).

Findings and adjustments after piloting

After piloting, several adjustments were made to the experiment. Firstly, a question was added to the questionnaire which asked, '*Have you ever used/experienced virtual reality (VR) before?*'. This was added to understand whether the novelty of using VR technology might affect how participants feel about the environments and therefore influence the findings.

Another adjustment was made regarding the device to measure HR and BP. During piloting, an upper arm cuff was used to measure HR and BP which was uncomfortable for some participants and made the experimental procedure feel very clinical. Wearing the upper arm cuff also meant that the participant needed to be wearing appropriate clothing for the measurement to be taken (e.g., short sleeve shirts, rolling up sleeves etc). For participants to feel more comfortable during the study, the upper arm cuff was replaced with a monitor which can be worn on the wrist. Wrist monitors have been found to be comfortable and reliable similar to monitors on the arm (de Lusignan et al., 2000). The monitor used was a *Scian* wrist type automatic digital blood pressure monitor (Model LD-753) (Scian, 2024). Another advantage to wearing a wrist monitor is that it also does not require certain clothing to be worn to take part.

During piloting, two laptops were used to run the experiment. One laptop was used to present the stressor task (traffic videos) and a second laptop was used for the Qualtrics questionnaire (Hewlett Packard EliteBook 830 G8 Notebook PC, 13" display). This decision was made so that participants did not need to go between different tabs/windows to find the questionnaire and videos. However, feedback from the pilot participants said that the amount of technology was confusing and it would be better, and the experiment would run more smoothly, if the stressor videos could be combined into the questionnaire on Qualtrics. Therefore, the stressor task was incorporated into the questionnaire on Qualtrics and the extra laptop was removed. This resulted in a seamless experiment which participants found easier to follow. This also reduced the duration of the experiment as participants did not need to spend time going backwards and forwards between screens.

It was noticed during the stressor task (traffic videos), that some participants adjusted the volume and wanted to reduce the sound of the loud, stressful traffic. The volume was set high so that the task would act as a stressor and this needed to be controlled for all participants so that everyone listened at the same, safe volume (68 decibels (dBA)). In main recruitment, all participants were verbally instructed to not adjust the volume at any time throughout the experiment.

6.5. Results

6.5.1. Descriptive statistics

Descriptive statistics of the sample's characteristics are presented in Table 6.8. As part of the questionnaire, participants were asked to complete several demographic and socioeconomic questions including age, gender, ethnicity, and household type. The largest age category was 35-44 years old (40%) (Median = 37, IQR = 12.25), the majority were women (69%) and White or White British (81%), and the largest household composition category was couples with dependent children (34%). It was also required for participants to indicate whether they had had any experience of using VR prior to taking part in the study of which the majority had had prior experience (71%).

Characteristic	N (%)
Age	
17-24	8 (14)
25-34	14 (24)
35-44	23 (40)
45-54	7 (12)
55-64	6 (10)
Gender	
Woman	40 (69)
Man	18 (31)
Ethnicity	
White or White British	47 (81)
Asian, or Asian British	5 (9)
Black, Black British, Caribbean or African	2 (3)
Mixed or multiple ethnic groups	1 (2)
Other ethnic group	3 (5)
Household type	
Couple with dependent children	20 (34)
Non-retired couple, no dependent children	16 (28)
One non-retired person	8 (14)
Retired couple, no dependent children	1 (2)
Other multi-person household	13 (22)
Prior VR experience	
Yes	41 (71)
No	17 (29)

Table 6.8. Sample characteristics.

Averages for each of the 8 outcomes after each stressor and VR environment are presented in Table 6.9. Firstly, stress was higher prior to viewing each of the VR environments (post stressor) than after viewing the environments (see Figure 6.6). After viewing VR environments, stress was highest after viewing the environment with lots of

people ($M = 7.14$, $SD = 2.33$), compared with viewing the environments with either no people ($M = 5.98$, $SD = 1.97$) or a few people ($M = 6.03$, $SD = 1.86$). Similarly, hedonic tone was higher after viewing each of the VR environments compared to before; this was highest after viewing the environment which had a few people ($M = 14.50$, $SD = 1.22$), compared to no people ($M = 14.05$, $SD = 1.65$), and lots of people ($M = 13.86$, $SD = 1.73$) (Figure 6.7). Energy was lower after viewing all three environments compared to before; this was lowest after viewing the environment with no people ($M = 11.48$, $SD = 2.35$) compared to few people ($M = 11.93$, $SD = 2.06$) and lots of people ($M = 11.98$, $SD = 2.00$) (Figure 6.8).

	No people		Few people		Lots of people	
Outcome (units/scale)	Pre-environment	Post-environment	Pre-environment	Post-environment	Pre-environment	Post-environment
Mental well-being (stress) (4-16)	8.48 (2.85)	5.98 (1.97)	8.81 (3.07)	6.03 (1.86)	8.67 (3.08)	7.14 (2.33)
Mental well-being (hedonic tone) (4-16)	12.66 (2.57)	14.05 (1.65)	12.36 (2.67)	14.50 (1.22)	12.19 (2.73)	13.86 (1.73)
Mental well-being (energy) (4-16)	10.79 (2.67)	11.48 (2.35)	10.07 (2.92)	11.93 (2.06)	10.02 (2.84)	11.98 (2.00)
Perceived restorativeness (0-10)	-	5.99 (1.94)	-	5.67 (2.04)	-	4.45 (1.88)
State social connectedness (10-70)	-	42.86 (10.04)	-	50.07 (8.16)	-	48.45 (9.15)
Heart rate (bpm)	72.89 (15.00)	71.42 (14.69)	71.61 (13.34)	70.37 (14.84)	70.38 (13.62)	71.48 (14.85)
Systolic blood pressure (mmHg)	126.37 (10.22)	124.48 (10.37)	123.41 (10.21)	121.27 (11.43)	123.75 (12.12)	122.52 (10.56)
Diastolic blood pressure (mmHg)	86.41 (9.31)	83.19 (8.33)	83.67 (9.11)	81.44 (8.92)	83.32 (7.90)	83.67 (9.27)

Table 6.9. Outcome measures following exposure to different environments. **Mean** (SD).

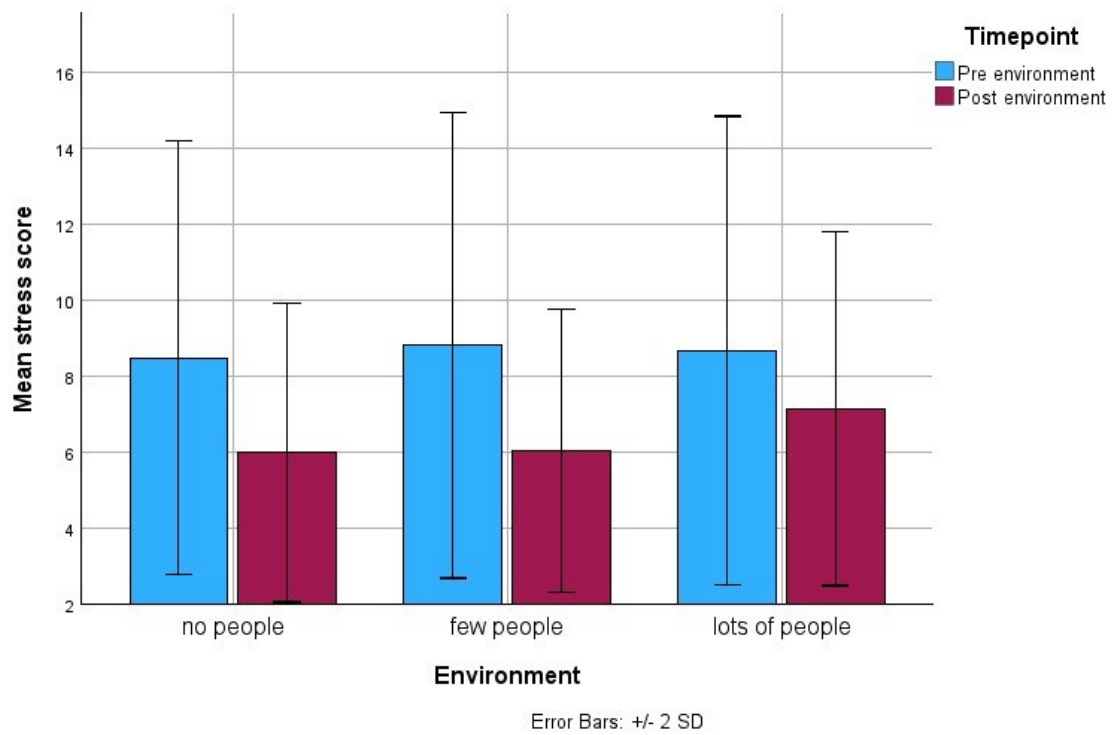


Figure 6.6. Mean stress for each experimental condition (range = 4-16).

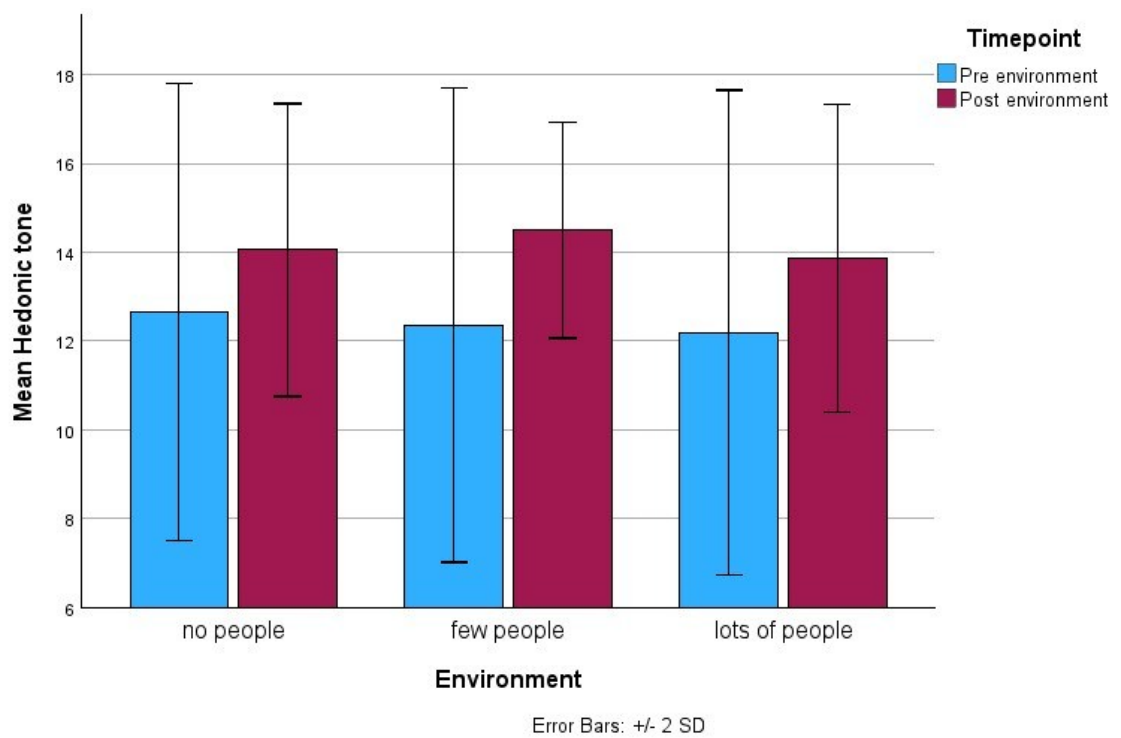


Figure 6.7. Mean hedonic tone for each experimental condition (range = 4-16).

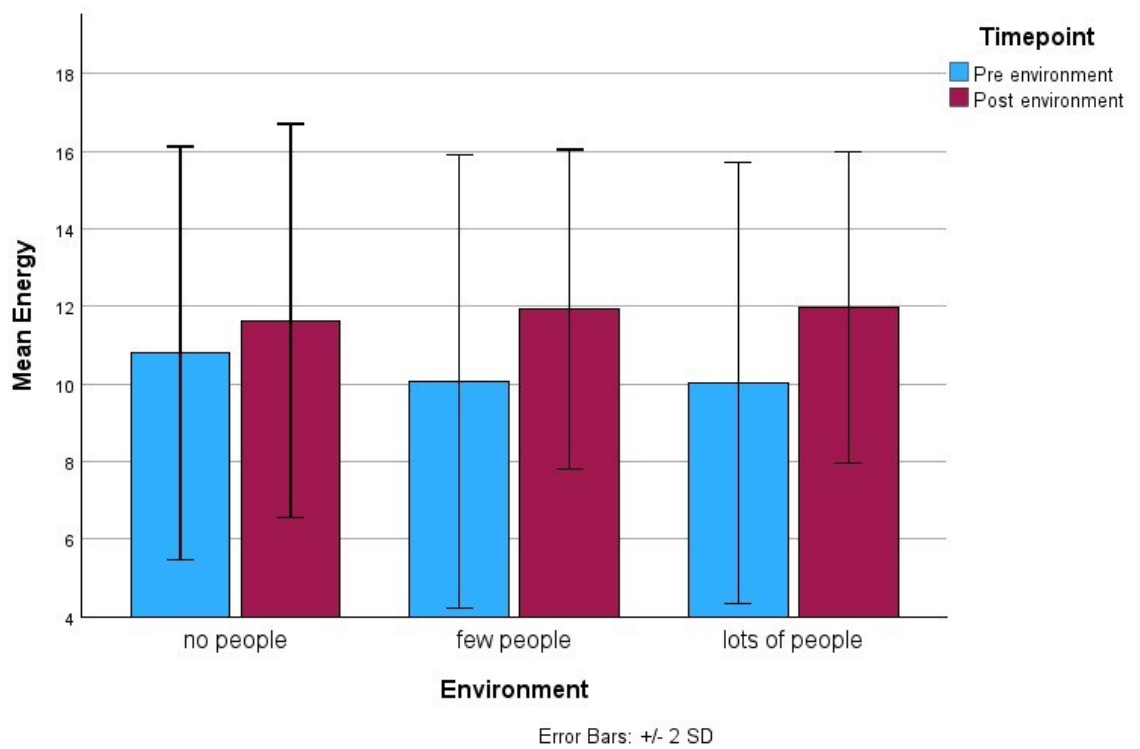


Figure 6.8. Mean energy for each experimental condition (range = 4-16).

All three environments were perceived as more restorative than the stressor environment (Figure 6.9). Perceived restorativeness was highest after viewing the environment with no people ($M = 5.99$, $SD = 1.94$), and lowest after viewing the environment with lots of people ($M = 4.45$, $SD = 1.88$).

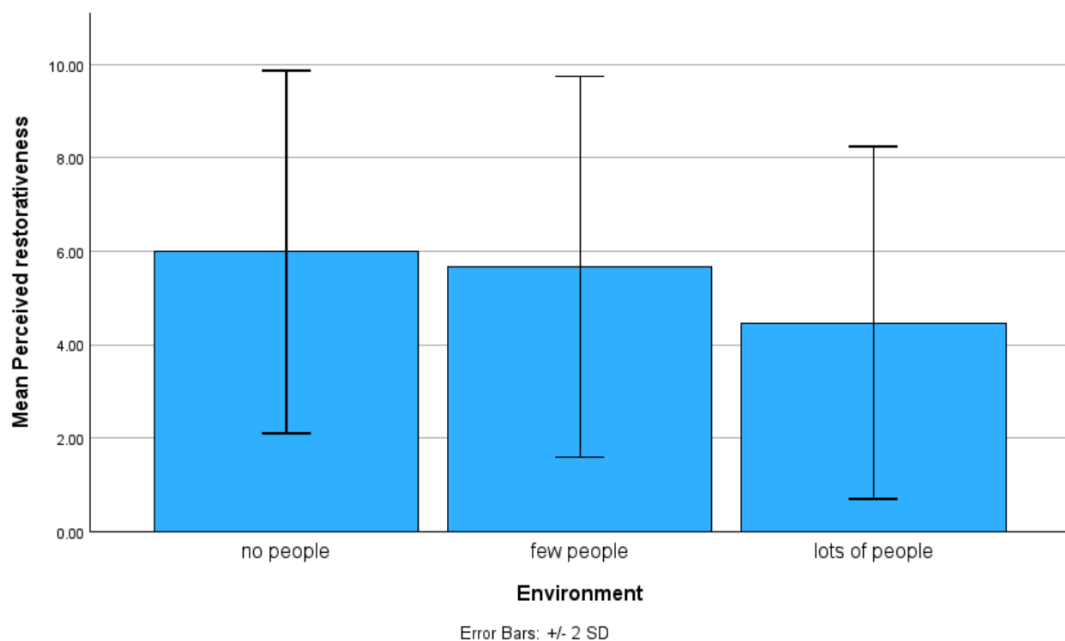


Figure 6.9. Mean scores perceived restorativeness for each experimental condition (range = 0-10), which also demonstrate a high left skew of the data.

State social connectedness was highest after viewing the environment with a few people ($M = 50.07$, $SD = 8.16$; see Figure 6.10) compared with lots of people ($M = 48.45$, $SD = 9.15$), and no people ($M = 42.86$, $SD = 10.04$).

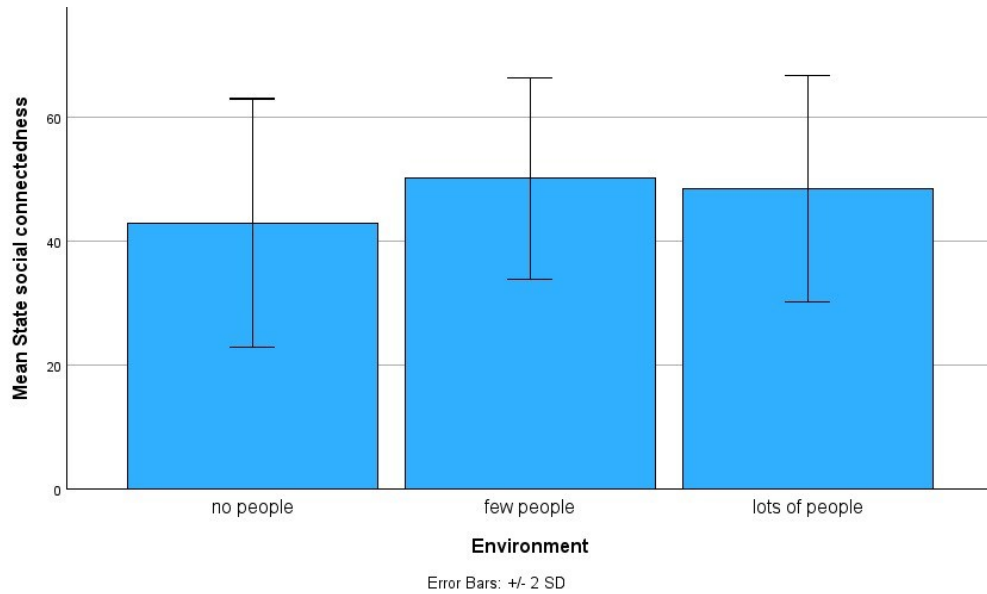


Figure 6.10. Mean scores state social connectedness for each experimental condition (range = 10-70).

Although differences were relatively small, heart rate decreased after viewing environments with no, or few, people in, and increased after viewing the environment with lots of people in (Figure 6.11). Heart rate was lowest after viewing the environment with few people in ($M = 70.37$, $SD = 14.84$) compared to no people ($M = 71.42$, $SD = 14.69$) and lots of people ($M = 71.48$, $SD = 14.85$).

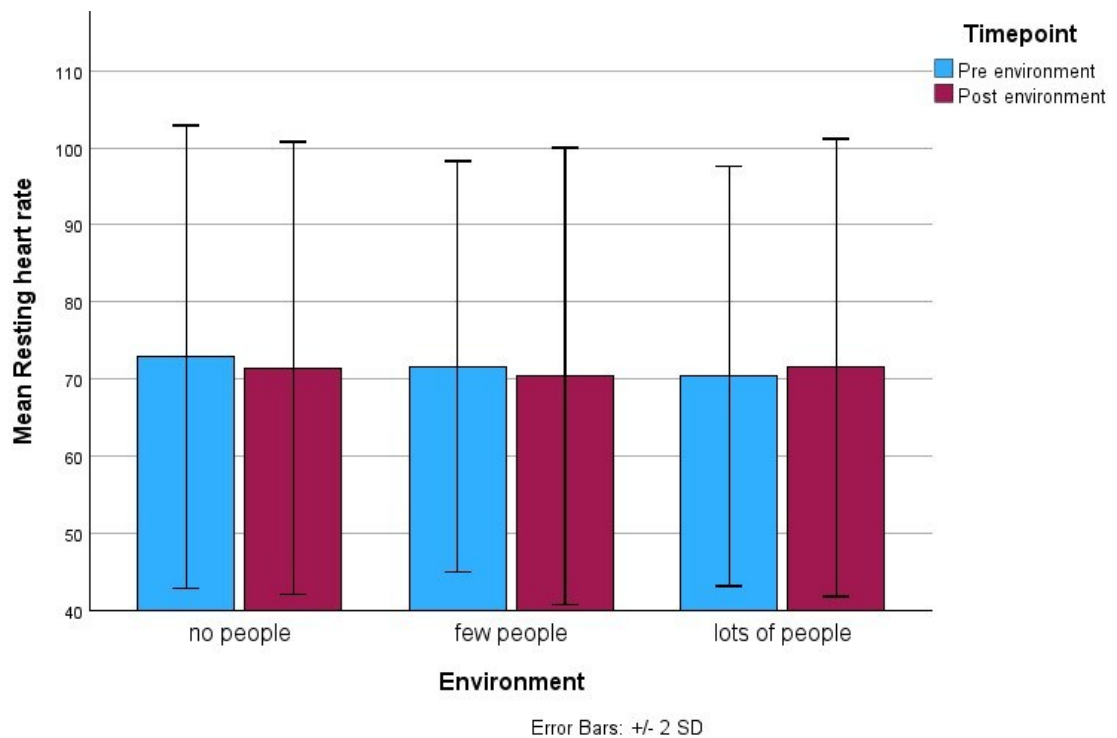


Figure 6.11. Mean heart rate (bpm) for each experimental condition.

Changes in both measures of blood pressure pre- to post-environment were relatively small across all environments (Figures 6.12 and 6.13). For systolic and diastolic blood pressure, these were lowest after participants viewed the environment with a few people. However, systolic blood pressure was highest after viewing the environment with no people ($M = 124.48$, $SD = 10.37$) and diastolic blood pressure was highest after viewing the environment with lots of people ($M = 83.67$, $SD = 9.27$).

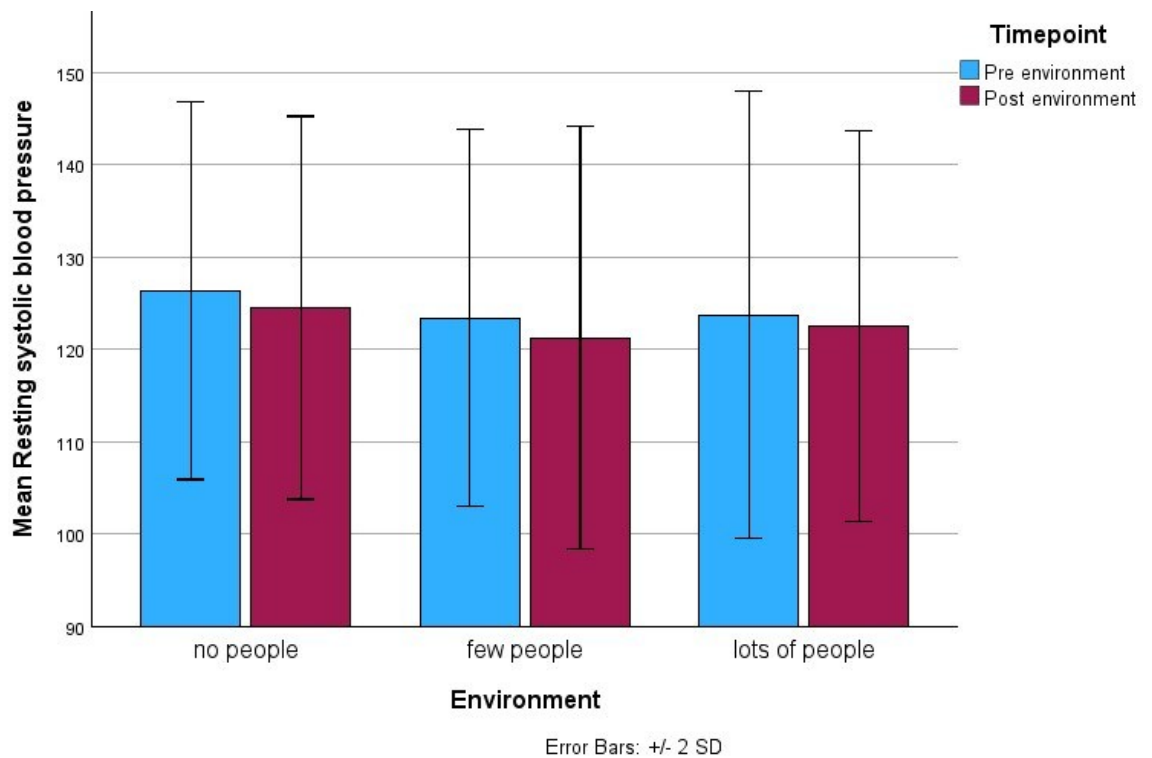


Figure 6.12. Mean systolic blood pressure (mmHg) for each experimental condition.

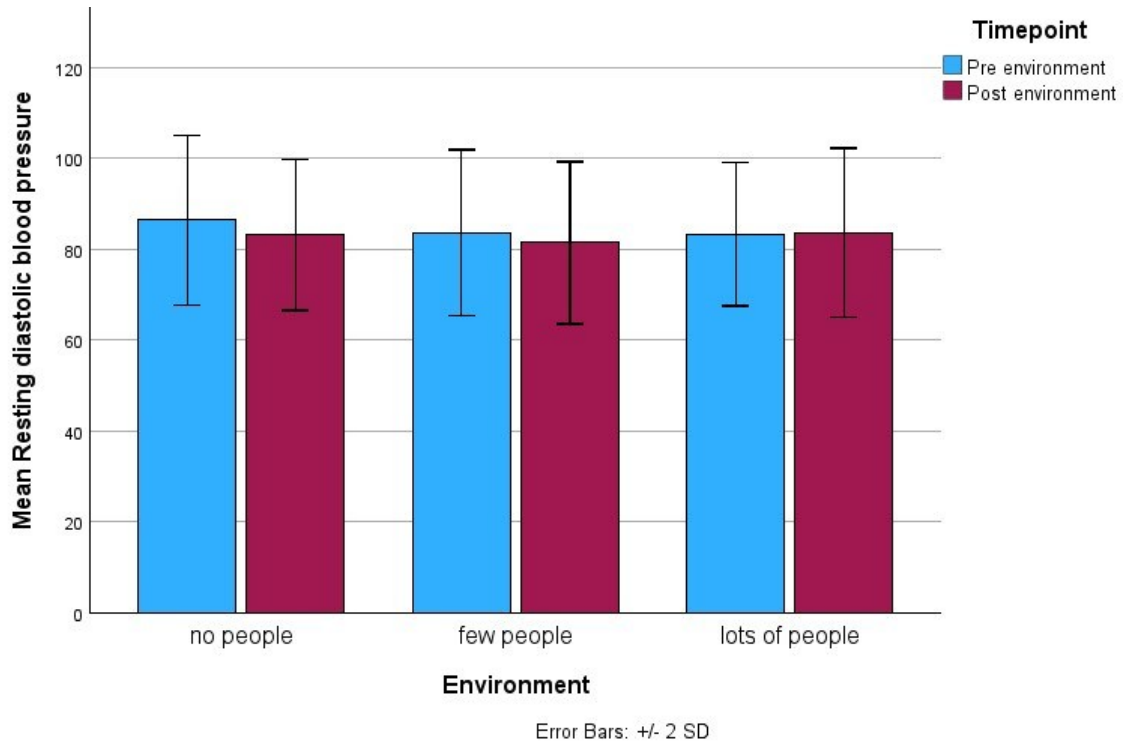


Figure 6.13. Mean diastolic blood pressure (mmHg) for each experimental condition.

Before correlational testing, checks for normality were conducted using Shapiro-Wilks tests. Many of the Shapiro-Wilks tests were significant (Table 6.10) which showed that the

distributions of scores of the outcome variables, across environments, were not normally distributed. As the linear mixed-effects model is a robust measure to violations of nonnormality and skew in self-reported outcome measures is common, the data was not transformed and a non-parametric alternative was not deemed necessary.

Variable	W	df	p
Mental well-being (stress)			
- No people	0.87	58	< 0.001*
- Few people	0.89	58	< 0.001*
- Lots of people	0.94	58	0.004*
Mental well-being (hedonic tone)			
- No people	0.88	58	< 0.001*
- Few people	0.84	58	< 0.001*
- Lots of people	0.88	58	< 0.001*
Mental well-being (energy)			
- No people	0.96	58	0.04*
- Few people	0.96	58	0.09
- Lots of people	0.95	58	0.01*
Perceived restorativeness -			
- No people	0.97	58	0.13
- Few people	0.99	58	0.74
- Lots of people	0.98	58	0.49
State social connectedness			
- No people	0.99	58	0.89
- Few people	0.96	58	0.04*
- Lots of people	0.98	58	0.28

Table 6.10. Output from Shapiro-Wilks test for normality. *Indicates variables which are non-normally distributed.

Spearman correlations

Due to some variables being non-normally distributed ($p < 0.05$), Spearman correlations were adopted as this statistical test does not assume normality in data (Table 6.11). Correlations showed that psychological outcomes were correlated with each other but not with the physiological measures. There was a particularly strong correlation between stress and hedonic tone. The physiological measures were not correlated with each other except for a strong correlation between systolic and diastolic blood pressure. The only

physiological measure which was correlated with a psychological measure was systolic blood pressure with perceived restorativeness, although this was a weak correlation.

	Mental well-being (stress)	Mental well-being (hedonic tone)	Mental well-being (energy)	Perceived restorativeness	State social connectedness	Resting heart rate	Resting systolic blood pressure	Resting diastolic blood pressure
Mental well-being (stress)		-0.72 < 0.001*	-0.48 < 0.001*	-0.40 < 0.001*	-0.27 < 0.001*	-0.06 0.31	0.002 0.97	-0.01 0.84
Mental well-being (hedonic tone)			0.55 < 0.001*	0.33 < 0.001*	0.32 < 0.001*	0.10 0.09	-0.08 0.18	-0.07 0.25
Mental well-being (energy)				0.23 < 0.001*	0.21 0.006*	-0.06 0.32	-0.09 0.11	0.02 0.74
Perceived restorativeness					0.19 0.02*	0.04 0.51	-0.14 0.02*	-0.10 0.08
State social connectedness						0.008 0.93	-0.11 0.19	-0.10 0.20
Heart rate							-0.01 0.86	0.05 0.36
Systolic blood pressure								0.68 < 0.001*
Diastolic blood pressure								

Table 6.11. Correlations between the 8 dependent (outcome) variables. *Correlation is significant at the 0.05 level.

6.5.2. Inferential statistics

Full SPSS outputs of all models presented next are included in [Appendix 26](#).

6.5.2.1. Stress

A linear mixed-effects model was conducted to investigate the effects of timepoint (pre and post environment) and environment (no people, few people, lots of people) on stress, with participant included as a random effect. After controlling for covariates, there was a statistically significant main effect of timepoint which indicated that stress was lower post-environment compared to pre-environment ($F(1,285) = 113.56, p < 0.001$). There was also a significant interaction between timepoint and environment ($F(2,285) = 3.13, p = 0.05$). Posthoc Bonferroni-corrected pairwise comparisons showed that there was a smaller reduction in stress after viewing the environment with lots of people ($M_{diff} = -1.53, SE = 0.37, p < 0.001, 95\% CI [-2.26, -0.81]$) compared to after viewing the environment with no people ($M_{diff} = -2.51, SE = 0.37, p < 0.001, 95\% CI [-3.24, -1.78]$) or few people ($M_{diff} = -2.78, SE = 0.37, p < 0.001, 95\% CI [-3.50, -2.05]$). This suggests that viewing the environment with no people or few people were most effective in reducing stress (Figure 6.14). For covariates, people reporting their household type as 'other' were significantly more stressed ($M = 8.09, SD = 3.23$) than people reporting their household type as 'couples with children' ($M = 6.98, SD = 2.32$) ($F(1,46) = 5.92, p = 0.02$). Additionally, higher baseline stress was predictive of higher reported stress throughout the experiment ($F(1,48) = 11.07, p = 0.002$).

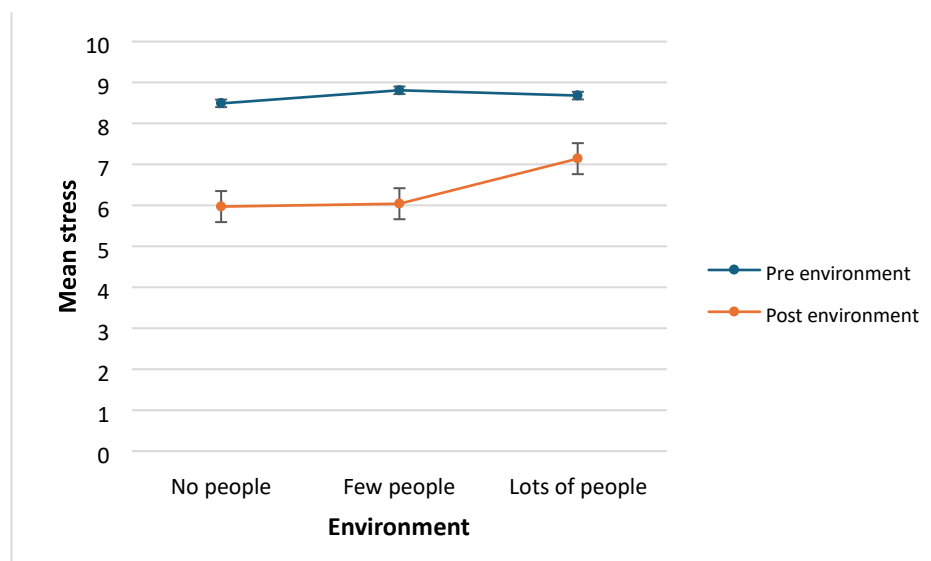


Figure 6.14. Interaction plot for stress showing adjusted means across timepoint and environment ($p = 0.05$).

6.5.2.2. Hedonic tone

A linear mixed-effects model was conducted to investigate the effects of timepoint (pre and post environment) and environment (no people, few people, lots of people) on hedonic tone, with participant included as a random effect. There was a statistically significant main effect of timepoint which indicated that hedonic tone was higher post-environment compared to pre-environment stimuli ($F(1,284) = 106.03, p < 0.001$). There was no interaction between timepoint and environment ($F(2,284) = 1.57, p = 0.21$) (Figure 6.15). For covariates, there was a main effect of baseline stress ($F(1,47) = 8.99, p = 0.004$), whereby higher baseline stress was predictive of lower hedonic tone but there were no other significant associations across covariates.

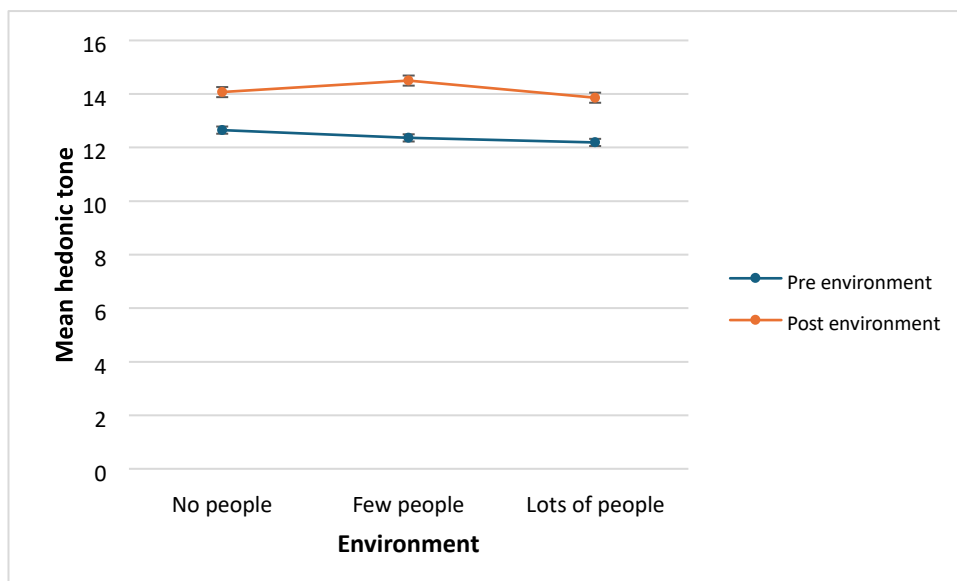


Figure 6.15. Interaction plot for hedonic tone showing adjusted means across timepoint and environment ($p = 0.21$).

6.5.2.3. Energy

A linear mixed-effects model was conducted to investigate the effects of timepoint (pre and post environment) and environment (no people, few people, lots of people) on energy, with participant included as a random effect. There was a statistically significant main effect of timepoint which showed energy to be higher post environment compared to pre environment stimuli ($F(1,285) = 68.68, p < 0.001$). There was also a significant interaction between timepoint and environment ($F(2,285) = 3.84, p = 0.02$). Post-hoc Bonferroni corrected pairwise comparisons showed there were larger increases in energy after viewing the environments with lots of people ($M_{diff} = 1.97, SE = 0.32, p < 0.001, 95\% CI [1.33, 2.60]$) or few people ($M_{diff} = 1.86, SE = 0.32, p < 0.001, 95\% CI [1.23, 2.50]$) compared with no

people ($M_{diff} = 0.82$, $SE = 0.32$, $p = 0.01$, 95% CI [0.18, 1.46]). This suggests that across all environments, participants experienced a greater increase in energy after viewing environments with people in them (Figure 6.16). For covariates, there was a main effect of baseline stress ($F(1,48) = 4.76$, $p = 0.03$), whereby higher baseline stress was predictive of lower energy throughout the experiment. Also, there was a main effect of baseline energy ($F(1,50) = 6.37$, $p = 0.02$), whereby higher baseline energy was predictive of higher energy throughout the experiment. Finally, loneliness was also significant ($F(1,49) = 5.93$, $p = 0.02$), where higher feelings of loneliness was predictive of lower energy throughout the experiment.

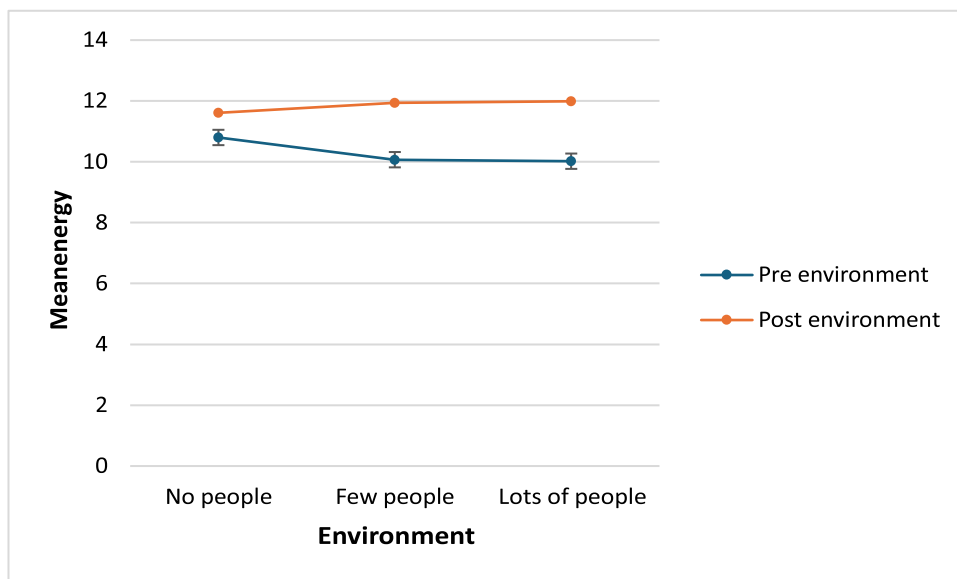


Figure 6.16. Interaction plot for energy showing adjusted means across timepoint and environment ($p = 0.02$).

6.5.2.4. State social connectedness

A linear mixed-effects model was conducted to investigate the effects of environment (no people, few people, lots of people) on state social connectedness, with participant included as a random effect. The model identified a statistically significant main effect of environment ($F(2,114) = 13.71$, $p < 0.001$). Post-hoc Bonferroni-corrected pairwise comparisons showed that state social connectedness was higher after viewing the environment with few people compared to no people ($M_{diff} = 7.27$, $SE = 1.46$, $p < 0.001$, 95% CI [3.73, 10.81]), and after viewing the environment with lots of people compared to no people ($M_{diff} = 6.65$, $SE = 1.46$, $p < 0.001$, 95% CI [2.11, 9.19]). The only covariate with a significant main effect was for connectedness to nature ($F(1,47) = 6.00$, $p = 0.02$) which

showed that having a higher connectedness to nature score was predictive of higher feelings of state social connectedness throughout the experiment.

6.5.2.5. Resting heart rate

A linear mixed-effects model was also conducted to investigate the effects of timepoint (pre and post environment) and environment (no people, few people, lots of people) on heart rate, with participant included as a random effect. There was no significant main effects of timepoint ($F(1,256) = 1.68, p = 0.20$) nor environment ($F(2,256) = 2.76, p = 0.07$) and there was no significant interaction between timepoint and environment ($F(2,256) = 2.60, p = 0.08$) (Figure 6.17). For covariates, people reporting their ethnicity as not white had generally higher heart rate ($M = 79.16, SD = 13.05$) than people whose ethnicity was white ($M = 69.51, SD = 13.99$) ($F(1,44) = 5.46, p = 0.02$). Additionally, higher baseline energy was predictive of lower heart rate throughout the experiment ($F(1,44) = 6.54, p = 0.01$). Also, there was a significant main effect of trait social connectedness ($F(1,43) = 4.76, p = 0.04$), whereby higher trait social connectedness was predictive of higher heart rate.

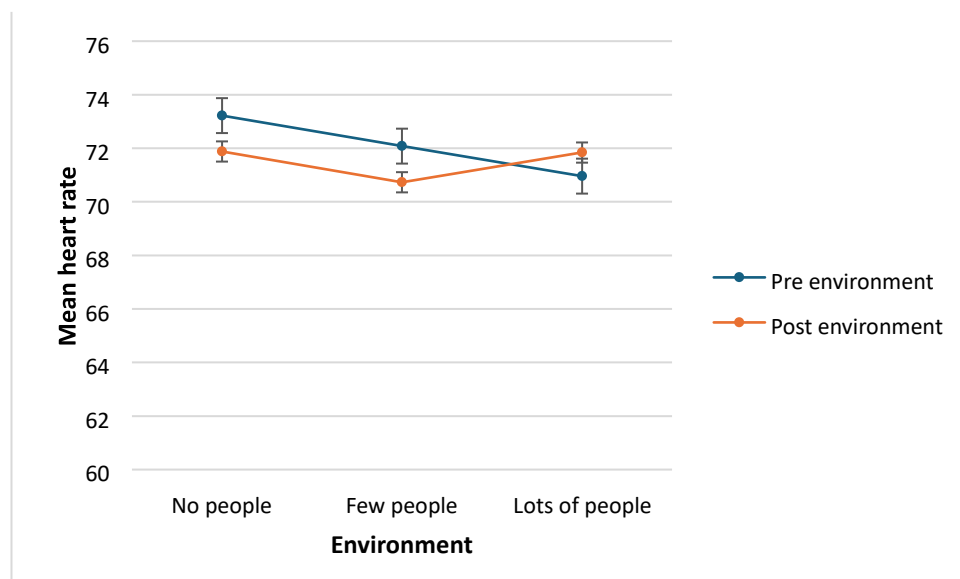


Figure 6.17. Interaction plot for heart rate showing adjusted means across timepoint and environment ($p = 0.08$).

6.5.2.6. Resting systolic blood pressure

A linear mixed-effects model was also conducted to investigate the effects of timepoint (pre and post environment) and environment (no people, few people, lots of people) on systolic blood pressure, with participant included as a random effect. There was a significant main effect for timepoint whereby systolic blood pressure was higher pre-environment compared

to post-environment ($F(1,258) = 4.48, p = 0.04$), but the interaction between timepoint and environment was not statistically significant ($F(2,257) = 0.18, p = 0.84$) (Figure 6.18). For covariates, men had higher systolic blood pressure ($M = 128.20, SD = 11.15$) than women ($M = 122.03, SD = 10.32$) ($F(1,44) = 4.76, p = 0.04$). Also, people reporting their household type as 'other' had lower systolic blood pressure ($M = 121.09, SD = 10.49$) than people reporting their household type as 'couples with children' ($M = 126.93, SD = 10.01$) ($F(1,44) = 3.97, p = 0.05$).

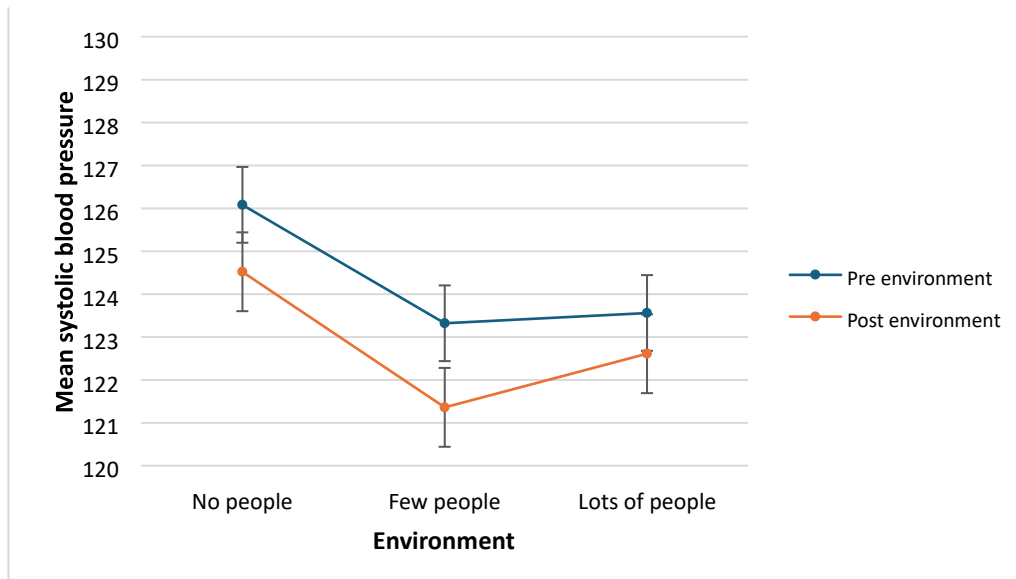


Figure 6.18. Interaction plot for systolic blood pressure showing adjusted means across timepoint and environment ($p = 0.84$).

6.5.2.7. Resting diastolic blood pressure

A linear mixed-effects model was also conducted to investigate the effects of timepoint (pre and post environment) and environment (no people, few people, lots of people) on diastolic blood pressure, with participant included as a random effect. A significant main effect for timepoint was observed, whereby diastolic blood pressure was higher pre-environment compared to post-environment ($F(1,256) = 8.78, p = 0.003$). There was also a significant interaction between timepoint and environment ($F(2,256) = 3.79, p = 0.02$). Post-hoc Bonferroni-corrected pairwise comparisons showed there was a greater reduction in diastolic blood pressure after viewing the environments with no people ($Mdiff = -3.05, SE = 0.96, p = 0.002, 95\% CI [-4.93, -1.17]$) and few people ($Mdiff = -2.32, SE = 0.95, p = 0.02, 95\% CI [-4.19, -0.45]$), compared to lots of people ($Mdiff = 0.46, SE = 0.95, p = 0.63, 95\% CI [2.34, 1.41]$). This suggests that diastolic blood pressure reduced only in environments with fewer

people in (Figure 6.19). There were no significant main effects for any covariates included in the model.

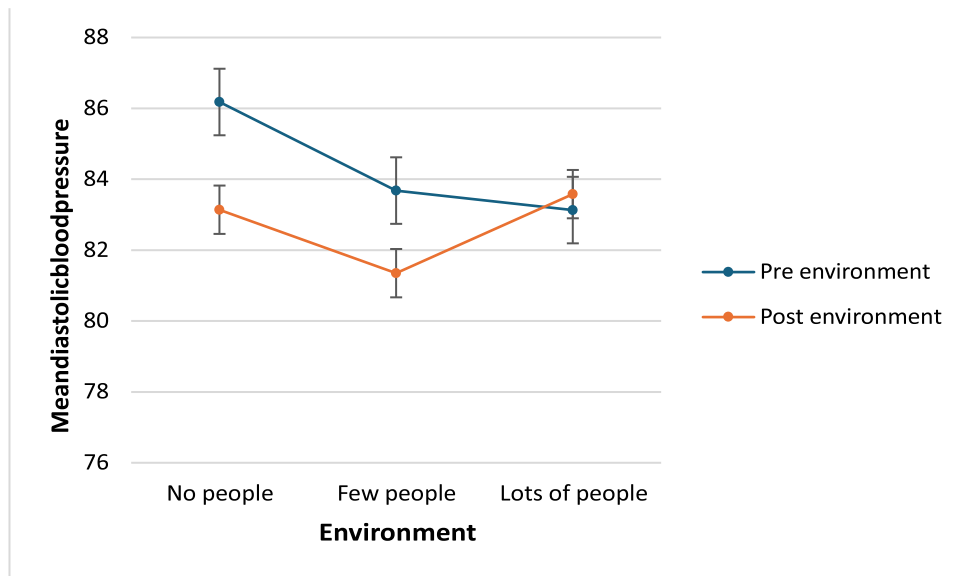


Figure 6.19. Interaction plot for diastolic blood pressure showing adjusted means across timepoint and environment ($p = 0.02$).

6.5.2.8. Age differences

To explore age differences, the dataset was split by the median age of participants (37 years old) and linear mixed-effects models were conducted comparing the two age groups. Again, the models were run for each of the 8 dependent variables. The differences between the models are reported here. With stress as the dependent variable, there was no significant interaction effect for the younger adult sample or older (Table 6.12). For hedonic tone, no differences were identified between the two age groups. For energy, there was only a significant interaction effect for middle-to-older participants ($F(2,129) = 3.31$, $p = 0.04$). For the middle-to-older group, post-hoc Bonferroni corrected pairwise comparisons showed there were larger increases in energy after viewing the environments with lots of people ($Mdiff = 2.30$, $SE = 0.46$, $p < 0.001$, 95% CI [1.40, 3.20]) or few people ($Mdiff = 1.52$, $SE = 0.46$, $p = 0.001$, 95% CI [0.62, 2.42]) compared with no people ($Mdiff = 0.63$, $SE = 0.46$, $p = 0.17$, 95% CI [-0.27, 1.54]), consistent with the overall findings. More differences were observed in relation to the physiological measures. Regarding heart rate, there was a significant interaction effect ($F(2,114) = 4.23$, $p = 0.02$) observed in the middle-to-older sample but not the younger. Post-hoc Bonferroni-corrected pairwise comparisons showed there was a greater reduction in heart rate after viewing the environments with no people ($Mdiff = -2.71$, $SE = 0.85$, $p = 0.002$, 95% CI [-4.41, -1.01]) and few people ($Mdiff = -0.17$, $SE =$

0.85, $p = 0.85$, 95% CI [-1.85, 1.51]), compared to lots of people ($M_{diff} = 0.67$, $SE = 0.85$, $p = 0.43$, 95% CI [-1.01, 2.35]). There were no significant interaction effects for the systolic blood pressure of younger or middle-to-older participants. Similarly for diastolic blood pressure, a significant interaction effect ($F(2,114) = 5.41$, $p = 0.006$) was observed for middle-to-older participants but not younger participants. Post-hoc Bonferroni-corrected pairwise comparisons showed there was a greater reduction in diastolic blood pressure after viewing the environments with no people ($M_{diff} = -3.20$, $SE = 1.15$, $p = 0.006$, 95% CI [-5.47, -0.93]) and few people ($M_{diff} = -2.83$, $SE = 1.13$, $p = 0.01$, 95% CI [-5.08, -0.59]), compared to lots of people ($M_{diff} = 1.54$, $SE = 1.13$, $p = 0.18$, 95% CI [0.70, 3.78]). Full output and interaction plots are presented in [Appendix 27](#).

	Younger (37 yrs and younger)			Older (38 yrs and older)		
	Timepoint	Environment	Interaction	Timepoint	Environment	Interaction
Stress	< 0.001	0.52	0.22	< 0.001	0.03	0.19
Hedonic tone	< 0.001	0.70	0.63	< 0.001	0.06	0.25
Energy	< 0.001	0.65	0.19	< 0.001	0.46	0.04
Perceived restorativeness	-	< 0.001	-	-	0.01	-
State social connectedness	-	< 0.001	-	-	0.01	-
Resting heart rate	0.49	0.43	0.15	0.14	0.001	0.02
Resting systolic blood pressure	0.39	0.07	0.84	0.02	0.01	0.25
Resting diastolic blood pressure	0.05	0.23	0.53	0.02	0.003	0.01

Table 6.12. Main effects of timepoint, environment and interaction for each dependent variable comparing younger and middle-to-older participants (p values).

6.5.3. Qualitative outcomes

During the brief qualitative interview at the end of the experiment, one of the questions involved asking participants which of the three environments they preferred. For some

participants, this was not a straightforward answer and a key aspect which arose from the question was that their response was conditional on how they felt; this will be discussed further later on. Despite this, all participants did provide an ultimate preference which resulted in the environment where a few people were present being the most preferred environment (N = 32) followed by no people (N = 19), and lastly lots of people (N = 7). The fact that this was far from unanimous demonstrates that the quantitative findings on wellbeing, perceived restorativeness, and physiological indices, cannot reflect all the factors accounted for with a more generic preference.

A note needs to be made regarding how participants interpreted and responded to the interview questions, and therefore the data which has made up the identified themes. Interestingly, participants often responded to questions about the virtual environments by referring to real life experiences in UGS. For example, participants would state which virtual environment they preferred and then give justification for this based on a real example and relate their answer to their day-to-day life. This can be seen as a positive reflection on the immersiveness of the environments which participants were viewing and leads onto one of the key themes identified which is '*VR as an immersive tool*' which will be discussed more in the presentation of themes below (sub-section 6.5.3.5). When discussing their preferences and what they liked or disliked about the environments they had seen, participants talked about how they would usually use a greenspace in their daily lives, what they preferred generally in a space and how they have experienced crowding in real spaces. The semi-structured nature of the interviews allowed for this extended discussion and provided depth and detail into why participants preferred one environment over another.

"Obviously it tries to mimic reality. And then you compare in your head with reality".

(Jade 39 yrs, **1,3,2**)

An overriding dialogue which was voiced by several participants was that preference for an environment was conditional on their needs. Their preference for the number of people in a space, and what they go to an UGS for, depended on what their mood was at that time and what they needed from a space in that moment. For example, if they had had a stressful day around many people, then they would prefer a space that they can escape into and be away from other people.

"Depends how your day has been. If you've gone after work and it's been a stressful busy day and lots of people and lots of things going on, like my work, I would

probably think it would be nice to sit with nobody around for a few minutes". (Rose 57 yrs, 2,1,3)

Again, participants reflected on their daily lives and gave examples outside of the virtual experience such as if they were visiting a space to socialise or go to on their lunch break from work.

"If I was going to socialise then I'd be fine with the busier one. But if I'm just people watching and wanting to take it slower, like having lunch or something, then I'd probably go to the middle one [environment 2 – few people]. If I was feeling a bit 'meh' then I would probably like the totally isolated one". (Autumn 36 yrs, 3,2,1)

So, despite participants providing an initial preference for an environment, this was often followed by a discussion around conditionality and what participants would need at different times if they were visiting that space in real life. It is important to present this dialogue here as an overarching context to the themes which will be outlined next.

From the 58 brief interviews, analysed using the framework method, five main themes were identified. An example of the framework, codebook, and thematic map are presented in Appendix [29](#), [30](#) and [31](#). The first theme explains how participants found social comfort in less crowded spaces. The second theme outlines the experience of being alone in the empty UGS and the feelings of participants in this environment. The third theme illustrates the importance of sound in the virtual UGS experience. The fourth theme revolves around navigating crowding, and participants thoughts about the crowded UGS, including pros and cons of being in such a busy space. And finally, the fifth theme encapsulates the technology used and the use of VR as an immersive tool. These themes will now be discussed in greater detail, with key quotes to illustrate each theme. Each quote is accompanied with the participant pseudonym, their age, and the order that the VR environments were experienced in.

6.5.3.1. Theme 1: Social comfort in less crowded spaces

The first theme describes how the majority of participants found comfort being in the UGS which had a few people in, and that this was their preference out of the three environments. There appeared to be a good middle ground whereby some people can be present in a space and it will not negatively impact the visit and can instead add to the experience. This seemed to be a 'goldilocks effect' of there being just the right number of people present in the UGS to still be able to enjoy the space.

"I think the most comfortable one was the final one [environment 2 – few people] when there weren't that many people but there were some people to give it a bit of atmosphere and a bit of life".

(Oliver 43 yrs, **1,3,2**)

"Yeah I'd probably go for the second one [environment 2 – few people] where there were some people but it wasn't crowded". (Glenn 53 yrs, **1,3,2**)

When discussing the preference for this environment, several reasons were highlighted. Firstly, some participants spoke about people watching and being able to do this in a space where people are present, noting that they were still able to do this in VR.

"The more people that came in, the more I then just started kind of people watching. Although they were static, I was people watching. I'm a people watcher".

(Violet 36 yrs, **1,2,3**)

"I quite like people watching in real life so...I thought that (the people) was actually the most interesting". (Willow 28 yrs, **1,3,2**)

Some participants went on to say that people watching can be relaxing because it gives them something to focus on in the space.

"I am quite a people watcher. Even if I'm relaxing, I can still relax by kind of just looking at people at the same time. So, I think having a couple of people was fine because it keeps me interested and allows me to relax". (Aurora 32 yrs, **3,1,2**)

In this context, people watching was discussed in terms of being an activity and something participants would consciously engage with, either as something they would usually do in their own lives or as an opportunity that the virtual space allowed. Alongside this, participants reflected on their directed attention in the different environments and some stated that their attention was drawn away from the nature and instead onto the people when the space was populated. Some said that as the environments got busier, the people were the dominant feature of the space, so the more they focused on the people, the less they focused on the natural landscape.

"In the first one [environment 1 - no people], I was putting my attention on the nature, and then in the second and third one, I was putting the attention on the people". (Ewan 34 yrs, **1,2,3**)

“In the first one [environment 1 – no people], I noticed the trees and the sky and just like the set-up of the park. You could appreciate it. In the second one [environment 2 – few people], I was aware of where the people were positioned, either by the fountain or over there. In the third one [environment 3 – lots of people], just even more focus on the people, like not even seeing the environment”. (Ivy 20 yrs, **1,2,3**)

In addition to seeing people from a distance in the space and enjoying people watching and focusing their attention on people, the environment with a few people present also allowed some participants to feel more socially connected.

“I felt the difference. It gave me the sense of belonging and connectedness with the people”. (Jasper 49 yrs, **2,3,1**)

Even if participants didn't feel like they wanted to interact with the other people about, they derived comfort in knowing that they could interact if they wanted to and that there were other people around, so did not feel alone.

“Environment 2 [few people] would be my preference given that there's a bit of human interaction or potential for human interaction”. (Heath 43 yrs, **2,3,1**)

“Probably number 2 (is my favourite) [environment 2 – few people] because you still get that connection as there's still some people around and you don't feel like you're alone”. (Jasmine 24 yrs, **3,2,1**)

Another reason why some participants preferred environment 2 was because the space with a few people reflected normality and was the closest to how they would experience an UGS in their day-to-day life. Participants expressed comfort in this normality. Participants expected there to be other people around, especially on a sunny day (which the VR environments represented). Some participants even spoke about how the virtual UGS looked like a park which they knew and they liked the environment which was the most normal for them.

“Environment 2 [few people] was the best because it seemed the most normal. It makes you feel comfortable. It's the most normal with only a few people around”. (Dale 37 yrs, **2,1,3**)

Finally, some participants' preference for the environment with only a few people in was purely practical – seating was limited in the crowded environment and so the space with fewer people was preferred due to the space and seating that this allowed for.

"I think I would prefer to go to the one with less people [environment 2 – few people], but I didn't feel less comfortable with more people. It's just there's more places to sit if there's less people. [...] I always go and sit if there's less people".

(Niamh 48 yrs, **1,3,2**)

This first theme highlights the preference that most participants had for being in an UGS which had a few people around. Participants also expressed their thoughts around being alone in the empty UGS and the pros and cons that came with being alone. This is encapsulated in the next theme.

6.5.3.2. Theme 2: Experience of being alone

A second theme identified explained broadly the experience of being in an UGS alone. This included reasons for wanting to be alone in an UGS, the feelings that come with being alone in a space, and the focus of attention in a space when there are no other people present. A prominent dialogue which was identified from some participants was the possibility for escapism when the environment had no people in. Participants explained their reasons for visiting an UGS which included the ability to escape and be away from people, the world and its stressors. Visiting a space alone and having no one around can aid in this potential for escapism. Furthermore, some participants spoke about wanting to be alone in the UGS.

"When going into nature, I want to get away from everyone. The whole point is for it to be quiet and to get away from everyone. Escape". (Coral 63 yrs, **2,1,3**)

"The last one [environment 1 – no people] felt like I'm here by myself and no one needs me and I can just relax and let my mind wander". (Layla 37 yrs, **3,2,1**)

"If I wanna feel free somewhere, I wanna be away from everyone. But I think that is because of the things around me... it annoyed me when everyone was around so much". (River 27 yrs, **2,1,3**)

Similarly, many participants spoke about the empty environment as a space which they found calming and relaxing.

"I did really like the one with no people [environment 1 – no people]. That was the most relaxing". (Holly 39 yrs, **3,2,1**)

In the previous theme, it is described that participants focused their attention on the people present rather than the environment they were in. Conversely, when participants were

alone in the space, some stated that their attention was drawn to the natural features which make up the space, including the trees, grass, and sky.

“With environment 1 [no people], I was looking at the trees and stuff because there were no people to look at”. (Tamala 37 yrs, 3,2,1)

“I focused on the nature aspect. Because that is definitely calming and relaxing. And the noises and the birds and things like that. And the blue sky and the trees”. (Aiden 37 yrs, 1,3,2)

Whilst some participants said that they found positive aspects of being alone in the UGS, such as being able to escape and that the environment provided a sense of calmness and relaxation, there were also negative aspects to being in the virtual UGS which had fewer or no people present. Firstly, some participants spoke about how they felt observed in the UGS and that they were more noticeable.

“The second one [environment 2 – few people], there was less people around, so you are more noticeable to them”. (Estelle 42 yrs, 3,2,1)

“Being all alone [environment 1 – no people], I would be like somebody is watching me from the houses. It was surrounded by houses. Maybe someone is watching me, someone might come and kidnap me!” (Savannah 19 yrs, 2,3,1)

Secondly, some participants felt more vulnerable the less people that were around. Participants questioned the empty space and wondered why there were no people around, which led to a sense of vigilance. Worry about vulnerability was implied by women in particular.

“But I was a bit on edge and wondered who could walk in... and waiting for someone to disrupt that thought. So actually, having some people around was quite calming from an isolation point of view”. (Dahlia 29 yrs, 2,1,3)

“Obviously as a female, I prefer there to be a few more people around”. (Niamh 48 yrs, 1,3,2)

A final negative aspect that arose for some participants was the sense of boredom they felt from being in the environment which had no people in. The space lacked energy and vibrancy which would usually come from people being present. Some participants described the space as having nothing going on and lacking an atmosphere.

“Environment 1 [no people] made me feel sleepy because there was nobody there... there was nothing happening”. (Dale 37 yrs, 2,1,3)

As well as the experiences that participants had of being alone in the virtual UGS, another theme is formulated which opposingly focuses on navigating crowding in the space and the experiences and thoughts participants had about crowdedness.

6.5.3.3. Theme 3: Navigating crowding

A third theme explains how participants experienced being in the crowded environment and their thoughts centred around navigating crowding. When participants spoke about crowding and the environment with lots of people in, it was mostly with negative connotations. Some participants spoke about the impact that overcrowding can have on personal space and movement within the UGS. Due to many people being present in the space, participants spoke about the lack of personal space and the need to have to think about where everyone else is, and how you can fit in spatially. A space being too busy was viewed as restricting movement and prohibiting being able to go or sit where you want.

“I just thought with the first one [environment 2 – few people], there was more freedom to move around. Whereas with the second one [environment 3 – lots of people], and having more people around, you would have to be aware and conscious of where you were and what you were doing because of other people around”. (Poppy 34 yrs, 2,3,1)

“You want to be able to move around freely and you couldn’t because there’s so many people. You wouldn’t be able to find a bench to sit on”. (Heather 64 yrs, 2,1,3)

This was a key reason which links back to why most participants preferred the environment which just had a few people present. This meant that there was still space for everyone to have their personal space and do what they want in the space; it provided a sense of free movement.

“If I wanted to go for a run through the park, there was space to do it. If I just wanted to sit and just listen to the birds for a bit, also not a problem”. (Jade 39 yrs, 1,3,2)

Some participants went even further to say that they would have wanted to leave the environment with lots of people in if it were real because it was too crowded and potentially find somewhere else to go.

“My least favourite would be the packed one [environment 3 – lots of people]. I counted like 40 plus people! I probably would have left that park in real life. Or moved to a little corner far away from everyone”. (Luna 27 yrs, 1,2,3)

Moreover, a couple of participants spoke about crowdedness in a positive light. Counter to what was expressed by participants about being alone (Theme 2) and that it can make you feel more noticeable in a space, here some participants spoke about how crowdedness can be helpful for blending into the crowd and not being as noticeable to others.

“No one would necessarily notice me because there’s a crowd. But if it’s just you or a few people, you’re more noticeable to everyone else. Kind of like watch the world go by and yeah... no one would take note of what you’re doing or what you’re thinking. So, in that respect I felt a bit more content. There’s lots of people around me doing their thing”. (Dahlia 29 yrs, 2,1,3)

On the other hand, one participant mentioned that blending in can be problematic and said that if they were in a crowded space in real life then they would worry about losing their children.

“But I know sometimes when it’s really busy and you’re trying to locate your children... when I see a busy park, even though my kids are much older, I still have that apprehension of trying to keep an eye out for them”. (Amber 37 yrs, 2,3,1)

A final but prominent aspect to this theme was the impact of sound; a main reason for disliking the busiest virtual environment was due to the noise. Participants spoke about the noisiness that was created by the crowding and their preference for quieter spaces. Some participants also spoke about not being deterred by the visual representation of the crowds, but it was instead the sound of the crowd that was an issue.

“It’s the sounds of chatter which really annoys me. That’s why I rank it [environment 3 – lots of people] at the bottom. I wasn’t annoyed by the crowd but annoyed by the voices”. (Ewan, 34 yrs, 1,2,3)

This leads onto a broader theme around the importance of sound in experiencing the virtual environments.

6.5.3.4. Theme 4: The importance of sound

A fourth key theme describes the importance of sound and its contribution to the experience of the virtual UGS. As highlighted at the end of the previous theme, there was a

large emphasis placed on sound and how some participants experienced the crowdedness and expressed a particular dislike for the sounds that accompanied the crowding. As well as the sound of the people, participants also spoke about the sound of birdsong in a positive manner. Participants expressed their enjoyment of birdsong and highlighted its relaxing effect.

"I liked the sound of the birds. That was really peaceful and really calming". (Poppy 34 yrs, **2,3,1**)

Some found it most noticeable in the environment which was empty of other people and some participants also spoke about how hearing the birds encouraged them to look around the space to try and see them. This links back to Theme 2 which outlined that participants attention was especially drawn to nature when they were alone in the empty UGS. When the space was crowded, some participants expressed that the noise from the crowd drowned out the sound of the birdsong.

"I like watching birds and looking at the trees. Normally you would see the birds or would be looking for the sound. So, I think I spent a lot of time looking at the trees". (Jade 39 yrs, **1,3,2**)

"It was too crowded [environment 3 – lots of people]. Too noisy [...] The noisy one, you couldn't hear the birds singing or anything". (Cliff 62 yrs, **3,1,2**)

As well as discussing likes and dislikes for the sounds which were audible in the environments, some participants also spoke about how the inclusion of the audio stimuli contributed to the environment feeling real and more immersive.

"I think the sounds help immerse you. I think they enhance it. If you didn't have the sound, it would feel less like you're in a virtual world". (Sierra 42 yrs, **2,1,3**)

"You do feel like you're there because you can hear the surrounding sounds". (Rose 57 yrs, **2,1,3**)

Participants spoke about the importance of the sound which accompanied the visual stimuli and thought that the experience may have been different if the sounds were not included. Overall, it was clear that the sound of the environments drew the attention of participants in both positive and negative ways and contributed to the overall feeling of realism of VR. This is connected to the final theme which illustrates VR as an immersive tool and describes the components which contribute to this theme.

6.5.3.5. Theme 5: VR as an immersive tool

The final theme which was identified encompasses the practical use of VR and its ability to be an immersive research tool. One aspect to this was the sense of presence and that the VR environments were realistic enough to feel like participants were actually there in the different environments. There was a disconnect from the outside world, and participants could feel a sense of presence in the VR environment.

"It's quite interesting to go into a different space... it's like you're into a different world aren't you?! [...] You forget your own world". (Rose 57 yrs, 2,1,3)

Some participants likened the virtual UGS to a real environment which they were familiar with, and this in turn increased its level of realism. They wondered whether the environment had been designed based on an existing space and said that it reminded them of somewhere they knew.

"I mean I live near a park and it seems like that. It's got the fence all going around and its got the middle area, the social part... so you can definitely see that it is realistic". (Hazel 32 yrs, 1,2,3)

Whilst realism and feeling present in the virtual UGS was commented on positively, some participants also discussed how, even though it felt real, they were still aware in the moment that it was not. They expressed that the space was realistic enough but they still knew it was fake, i.e., they were not actually there.

"The virtual reality was descriptive enough to illustrate the sense of feeling of being in an environment like that". (Zahara 38 yrs, 1,2,3)

"It's amazing how effective it is even though it's not photo-realistic. I definitely did feel calmer". (Layla 37 yrs, 3,2,1)

Participants also discussed the more practical features of VR and commented on the graphics and detail of the space. Some participants reported flickering and lighting issues in relation to the graphics as well as features which they did not think were as realistic.

"I mean it was a bit flickery. It wasn't the best quality". (Eden 44 yrs, 3,2,1)

However, other participants noticed and appreciated the level of detail in the space.

"I like that it generated shadows. I had appreciation for the technical bits". (Rowan 23 yrs, 2,3,1)

"I felt pretty into it. It's very detailed and more detailed than what I thought I was expecting. I was looking at the individual leaves and how the fountain was made and the clouds in the sky. It felt pretty... you can stick it on at work and have half an hour of a park". (Sylvia 41 yrs, 1,2,3)

Similarly, some participants reflected on the movement which was possible with VR and appreciated the capability of being able to see all around themselves. Although some also commented on the inability to physically move in the space and that the people present in the space were static graphics which lacked movement.

"Whenever you look around, you see more opening up for you. You can look up and it's a full blue sky. It's really nice actually. I would like to be in a place with moving people. It was just static." (Savannah 19 yrs, 2,3,1)

Finally, some reflections were also made in relation to the benefits that VR can provide, such as for people to be able to access a greenspace. As previously mentioned by Sylvia, she said that she could have a work break and put the headset on. One participant also joked that they no longer need to go out to a park that day because they had taken part in the experiment and seen the virtual space:

"The experience was amazing, it was so fun! I was in a different world and could have been there all day. I don't need to go to the park today now!" (Summer 22 yrs, 2,1,3)

6.6. Discussion

This study experimentally tested whether the number of people present in an UGS has an impact on the perceived restorativeness of the space and feelings of social connectedness. A secondary aim was also to explore whether age has a modifying effect on these outcomes. Four research questions were posed: (1) What effect does crowdedness in an urban greenspace have on psychophysiological indicators of mental well-being? (2) To what extent does crowdedness impact the perceived restorative experience of urban greenspace exposure? (3) What effect does crowdedness have on feelings of social connectedness in an urban greenspace? (4) Are RQ1, RQ2, and RQ3 impacted by age? The findings of this study will next be discussed and structured by indicating how each research question has been answered to what extent the findings are consistent with previous literature, and how the findings extend previous literature.

6.6.1. Findings

The first research question asked, 'What effect does crowdedness in an urban greenspace have on psychophysiological indicators of mental well-being?'. Mental well-being was measured through three components: stress, hedonic tone, and energy, using the UWIST MACL (Matthews et al., 1990). In answer to the research question, results from the linear mixed-models suggested that of all the environments, participants felt least stressed after viewing the environment with no people present. For hedonic tone, increased hedonic tone was observed after viewing the VR environments compared to the stressor, however no significant effects between the VR environments were evident for this outcome. Whilst this showed the stressor stimuli to have good construct validity in that it did act as a stressor and was less enjoyable than exposure to the virtual UGS, it does not provide support for crowding having an impact on hedonic tone. Thirdly, with energy, the results of this study found that participants experienced a greater increase in energy after viewing environments with people in them. This finding aligns with some of the qualitative findings in this study, where it was mentioned that having a few people in the environment meant that the space had an atmosphere and life to it. Physiological outcomes were also experimentally tested in this study. While there were no significant main effects nor interaction regarding heart rate, both indicators of blood pressure showed main effects of timepoint indicating a restorative effect of viewing any environment. Furthermore, for diastolic blood pressure, there was a significant interaction which indicated a greater restorative effect when viewing environments with no, or a few, people in. This lends convergent validity to the comparable interaction term found with self-reported stress.

The finding of subjective stress in this study aligns with previous cross-sectional research which has suggested that lower levels of visitors in a greenspace are preferred when the purpose of visiting was for stress relief (Arnberger & Eder, 2015). Further, a novel aspect to this study, and one which has extended previous literature, is the inclusion of a measure of energy and how participants showed a greater increase in energy after viewing environments with people in them. When measuring mental well-being, energy is less represented as a measure and so this study has provided evidence of another facet of mental well-being. For physiological measures, this study's findings in relation to heart rate is in line with previous literature which has also reported no differences between similar conditions but has suggested that heart rate decreases over the duration of an experimental session (Anderson et al., 2017; Mostajeran et al., 2021; Spano et al., 2023).

Some research using heart rate as an outcome measure has suggested that interactivity is important for relaxation in natural virtual environments (Liszio & Masuch, 2019). The environments in the present study lacked interaction and participants were only able to passively watch and listen to the environments, so this could explain why no differences were found in heart rate. Previous research has also measured blood pressure after VR exposure to natural environments and found inconsistent results (Song et al., 2022; Spano et al., 2023; Sun et al., 2023), and to date blood pressure has not been measured to investigate the effect of varying numbers of people in the environment, so this study extends the research in this field and insofar as diastolic blood pressure is a good indicator of the stress response, lend support to self-reported findings regarding reduced stress in environments with fewer people in.

The second research question asked, 'To what extent does crowdedness impact the perceived restorative experience of urban greenspace exposure?'. As measured subjectively, the environments with few and no people in were perceived to be the most restorative, compared to the environment with lots of people in, which was perceived to be the least restorative. Therefore, crowdedness did impact the perceived restorative experience of UGS exposure. As above, actual restoration can further be inferred from the greater reductions in self-reported stress and diastolic blood pressure in the conditions with fewer people present too, lending support to self-reported perceived restorativeness effects. A theme identified in this study highlighted the importance of sound in UGS and one aspect of this was the sound of birdsong (theme 3). Birdsong was described by some participants as peaceful and calming and is in line with the wider literature base which supports the restorative potential of listening to birdsong (Ratcliffe, 2015; Ratcliffe et al., 2013; Zhu et al., 2020). The qualitative findings also align with the 'being away' component of ART (Kaplan & Kaplan, 1989). Theme 2 outlined the experience of being alone in the empty UGS and that it can be calming because of the sense of escape. However, this theme also outlined the negative aspects of this – that it can feel isolating and lead to feeling vulnerable. Feeling vulnerable and perceptions of safety are prominent topics often discussed in regard to being in greenspaces and so these results were in line with previous findings (Hong et al., 2018; Jorgensen et al., 2013; Lis & Iwankowski, 2021). Another study by Staats and Hartig (2004) looked at restoration in environments when being alone or with a friend. A key finding from the study suggested being with someone can enable restoration by providing safety, but, when safety is not a concern, restoration is enhanced by the absence of company.

Regarding the perceived restorativeness of an UGS and how too many people being present can have a negative impact, these results differ from previous literature. Some previous research has found that the inclusion of people in nature does not have any significant impact (positive or negative) on restorative outcomes (Neale et al., 2021). However, this study did not focus on UGS specifically and looked at the presence and absence of people, rather than crowdedness. They suggested the latter for future research, which this study has begun to address by isolating the effect of crowding on perceived restorativeness. Other research is in line with these findings whereby low or no presence of a social dimension is the most restorative environment for stressed individuals (Grahn & Stigsdotter, 2010).

The third research question for this study was, 'What effect does crowdedness have on feelings of social connectedness in an urban greenspace?'. In answer to this question, the results of this study suggest increased feelings of state social connectedness in the environments which had a few and lots of people in, compared to the empty environment. The more people that were in the environment, the more socially connected participants felt. There was a positive effect of crowding on feelings of social connectedness.

Additionally, one significant covariate identified in this study was that higher connectedness to nature was predictive of higher feelings of state social connectedness throughout the experiment, which aligns with previous research which has suggested an emotional commonality between these two (Cao et al., 2024). The qualitative findings also aid in answering this research question. Theme 1 explained that social comfort and connection can be experienced when there are people present in the UGS, but this was more prominent in the environment where there are some people present but not too many. Qualitatively, the majority of participants also preferred the environment which had a few people present in. Another theme which was identified in this study was about participants' navigation of crowding and the pros and cons of crowding in the UGS, including the ability to blend in, but also that crowding can lead to increased noise and lack of personal space and movement. Whilst people being present in a space can be socially beneficial, too many people can instead act as a deterrent.

The findings in this study which suggest that a few people are preferred in an UGS are in line with a previous study which has shown, through a questionnaire, that a few people being present is preferred over no people or many people (Nordh et al., 2011). The findings here also provide support for Prospect-refuge theory (Appleton, 1975), which suggests that people prefer environments which have a high level of prospect (expansive, clear vision)

and refuge (places to hide) (Gatersleben & Andrews, 2013). The environment in this study which had only a few people present would align with being able to provide refuge where people feel they can 'blend in' amongst others, but still not being too crowded so that they have a clear view of the environment (prospect). Overall, this study added to the literature by experimentally measuring state social connectedness in relation to viewing different amounts of people being present in an UGS. This study also provided wider support for the broader dialogue in the research field about the social well-being benefits of being in an UGS (Dinnie et al., 2013; van den Berg et al., 2019).

Integrating these outcomes, one of the overarching qualitative findings was the caveat that some participants reported that their preference for the UGS was conditional on what mood they were in or what they needed at the time. The fact that the kind of environment people prefer changes depending on current needs has previously been mentioned by scholars (Stoltz & Grahn, 2021), although there has been a lack of previous studies which provide experimental evidence of the notion. Additionally, the results from this study point towards there being a trade-off between feeling invigorated (energised and socially connected) in an UGS, and restoration from stress. A busier space may allow for feeling more socially connected, however the space may then not be perceived as restorative. And vice versa in that a less crowded space may be perceived as more restorative, however then there are less people around to feel socially connected. Whilst previous research discussing this trade-off is limited, some recent findings posit social connectedness as a mediator between embodied nature experiences in urban parks and psychological restoration (Cao et al., 2024). It is clear from the present study that the presence of people being in an UGS is an important factor in terms of feeling socially connected and also in terms of how restorative the space is perceived to be. Having other people around can be stimulating and beneficial in terms of connection, which humans are inherently drawn to building (Young, 2008).

The final research question posed for this study was, 'Are RQ1, RQ2, and RQ3 impacted by age?'. To answer this question, an exploratory investigation into age was conducted which divided participants into a younger and middle-to-older sample. It was found that the environmental differences in physiological indicators of stress reduction (diastolic blood pressure and heart rate) were only present in the middle-to-older sample, although it is noted that this group did have higher systolic and diastolic blood pressure at the beginning of the experiment. Similarly, greater increases in energy in response to busier environments

were found which were only present among the middle-to-older group. Overall, the benefits associated with different levels of crowdedness in UGS could be more pronounced for middle-to-older populations in relation to mental well-being (RQ1), and therefore could be linked to ageing. However, age did not appear to be an impacting factor on perceived restorativeness (RQ2) or feelings of social connectedness (RQ3) and rather are things that everyone needs for mental well-being. This exploration with age extends the literature base which has yet to explore age differences regarding crowding in UGS and the impacts on mental well-being, perceived restorativeness, and feelings of social connectedness.

6.6.2. Implications

The results from this study have added new evidence to the literature, suggesting that the impact of exposure to UGS on perceived restorativeness and wider mental well-being benefits is complex and potentially involves trade-offs. This study has shed light on the importance of the social aspects of UGS and the impact that crowding can have, which has so far received little attention in the field. Being alone and escaping into nature might be beneficial for some individuals at some times, however, this is conditional, and some people may prefer others to be present in UGS as it can increase their feelings of social connectedness and safety. Knowing that different people have different needs at different times can inform the planning and design of UGS in a way so that they cater for these nuances. For example, spaces can be designed which have areas for socialising as well as quieter, more private areas which allow for solitude and escapism. Additionally, UGS can be prioritised in areas which have high levels of loneliness in order to facilitate social connectedness. This leads onto a broader consideration which is the number of greenspaces which are available and accessible in urban areas. The more UGS there are, the more space there is for people to feel socially connected whilst also reducing the amount of crowding in the spaces. However, creating more greenspaces in cities may be challenging due the lack of space. Another possible application of these findings would be improving the management of existing UGS so that they can cope better with crowding. For example, increasing the amount of seating and adding accessible pathways.

This study has added to our knowledge about crowding in UGS and how it can impact the mental well-being of visitors. This is particularly relevant after the COVID pandemic which saw immense overcrowding in UGS. As suggested by Neale et al., (2021), people's tolerance for crowding may have changed since the pandemic, and for this study, may have influenced the negative views expressed towards the crowdedness. The pandemic also increased people's awareness of the mental well-being benefits that UGS can provide and increased

appreciation for these spaces (Office for National Statistics, 2021). Further, the findings from this study can also help to improve the implementation of green social prescribing. Green social prescribing supports people to engage in nature to improve their mental well-being (Department of Health and Social Care, 2023; Haywood et al., 2024). Considering social connectedness and social needs could help to tailor visits to nature to be optimally beneficial. For example, encouraging visits to a greenspace which is accessible but crowded, may not be helpful. On the other hand, encouraging visits to a greenspace as part of a social group, or an organised activity, may be more beneficial than advising visiting alone.

6.6.3. Strengths and limitations

This study has several strengths and limitations which will be outlined in this section. Firstly, a strength of this study was its novelty in investigating the impacts of the number of people present in an UGS and the perceived restorativeness and social connectedness outcomes. So far in the literature, the impact of other people present in a space is neglected, despite real life experiences of UGS often including other people. As this is an initial study on the topic, more evidence is needed to replicate the findings and further develop the evidence base. A second key strength of this study was the utilization of VR as a research tool, giving a high level of control over the stimuli which participants were exposed to. Each virtual environment was designed and created using Unity which allowed for each element of the environment to be carefully composed so that the effect of the number of people was isolated. An immersive environment could be created whilst simultaneously maintaining a high level of experimental control. Another strength of this study is the heterogeneity within the sample. Many studies in psychology involve student samples due to convenience and opportunistic sampling, and this study aimed to go beyond this specific population and be more generalisable (Arnett, 2008; Hanel & Vione, 2016). Whilst still opportunistic, and in a university setting, the participants recruited for this study were predominantly adults working within a wide range of professional services, rather than students or academic staff. However, while the sample included a wide range of ages and job roles, it did lack ethnic and gender diversity. The majority of participants were women and white.

A strength was that the VR environments shown to participants were immersive and described as being realistic enough to get a sense of presence in the space. However, some participants did comment on the graphics and quality of the environments (theme 5). The resolution and lighting was sometimes flickery, the virtual people lacked realism, and it was clear that the space was computer-generated and not photo realistic. This was a limitation

of the study and may have influenced participants experience of the virtual environments. However, creating a more photo realistic environment would have involved other methods such as 360 degree images or videos of real environments which would have then lacked control over the number of people present and other extraneous variables (e.g., weather, noise). Since the study has been conducted, a newer headset has been released (Meta Quest 3) which has double the graphic processing power of the Quest 2 and improved resolution. The latest technology, alongside more time and expertise in virtual environment design, may improve the quality of the VR environments which is something future research should consider when designing experimental virtual environments. An advantage for participants taking part in this study was that they only needed to attend once and could complete the study in a reasonable time (1 hour). However, this experimental design could have been limiting. Social desirability bias may have been present where participants may have guessed the aim of the study and adapted their responses to the self-reported questions. This is generally a limitation of within-subjects designs where participants view all levels of the independent variable. To mitigate this, the order of the VR environments was counterbalanced, however this may not have entirely eliminated the possible demand characteristics. By the third (last) VR environment, participants may have realised that the only thing changing between the environments was the amount of people. However, the environments were randomly ordered, which will have helped mitigate any such effect.

Reflections can also be made in regard to the recruitment process and limitations of the sample. Whilst the recruitment strategy aimed to be inclusive, in that not solely students and academics were targeted, this strategy was met with challenges. It was not clear before recruitment that there would be few staff working in the professional services who would meet the young adults age range (17-24 yrs). Therefore, the decision was made to widen recruitment to include students and academics. Again, this was met with challenges due to the time of year when the study was conducted (summer) which meant that there were few students and academics on campus. One of the aims of the study was to explore the impact of age on the outcomes of interest, however this was somewhat limited by recruitment challenges. Few younger participants 17-24 yrs were recruited and so the median split for looking at age differences (37 yrs) was older than first proposed for analysis (24 years). However, this investigation was a strength in that exploratory moderation analyses could be conducted which then revealed new insight into which interactions between crowdedness and psychophysiological outcomes might be generalisable across ages and which might be more pronounced to middle-to-older aged adults. Whilst this exploration was potentially

subjected to Type 1 errors, the findings presented here provide new interesting avenues for further research. Future research should consider age as a moderator in experimental designs and aim to recruit more young participants for comparison.

6.7. Conclusion

The results of this study shed new light on how other people being present in an UGS can impact the benefits gained from the space, including perceived restorativeness and feelings of social connectedness. Quantitative measures support that people prefer to be in a space with a few other people present, but which is not overcrowded. The qualitative measures provided more depth and showed that preferences can be conditional based on perceived needs and motivations. It is crucial to think more holistically about how UGS are experienced, and how this is influenced by the presence of other people. A more person-centred approach and understanding of what people need from a space warrants consideration. As this is a novel study, experimentally investigating the effect of people and crowding, further research is needed to pursue the following specific avenues for investigation. Firstly, future research could look at different aspects of people being present in UGS, such as groupings and placement of people, and people of different ages and ethnic groups being present. For this study, the age and ethnic diversity of the people represented in the UGS were kept consistent to avoid confounding, but future research could look at these different dynamics. In a similar thread, the participants recruited for this study lacked diversity and so future research could focus on other demographics such as ethnicity and gender, especially as some significant covariates were found in the present study. Future research should focus on the impact of age on mental well-being, restoration, and social connectedness outcomes, as this was only briefly explored in this study. Additionally, future research could capture the opinions of neurodiverse individuals in order to understand how they would experience the UGS with varying amounts of people in. This would provide a broader and more diverse understanding of the impact of crowding in UGS.

Chapter 7: General discussion

7.1. Introduction

The body of work presented in this thesis has explored several aspects of urban greenspaces (UGS) and their beneficial effects on mental well-being, including how these spaces are perceived by multiple age groups and the social benefits which these spaces can provide, how experimental research can be strengthened by recognising that using psychological and physiological measures can lead to different conclusions, and the use of immersive technology like VR as a tool for stimuli exposure. This chapter provides a summary of the research conducted as part of the body of work in this thesis and its theoretical and methodological contributions to the study of UGS and mental well-being. Overarching strengths and limitations of this thesis are then discussed, in addition to providing recommendations for future research and applications of the research for practice and policy. The chapter concludes with personal reflections about the process of conducting this research and an outline of how the body of work has been disseminated to date.

7.2. Contribution to knowledge

This thesis aimed to address three key areas in the field which have lacked evidence to date. It began with a broad qualitative exploration of how UGS are beneficial for the mental well-being of different age groups. A main theme surrounding the social aspects of UGS was identified in this study which was then taken forward into a larger experimental study in order to investigate how other people being present in an UGS can impact restorative and social connectedness outcomes. Alongside this, the thesis aimed to explore methodological decisions in relation to exposure methods and types of measures of mental well-being which are chosen for experimental research in the field. Therefore, two pilot studies were conducted in order to investigate this, and the findings informed and supported the design of the final experimental study.

In the body of work presented, several novel findings have been identified. Firstly, the initial qualitative study (Chapter 3) found similarities across four age groups which were demonstrated by four themes: UGS can provide a sense of escape; there are practical needs surrounding access and contact with UGS; being a space to share with other users; and the importance of seasonal multi-sensory components. The study showed that there are also differences regarding interactions across age groups in that adolescents express wanting

their own space and did not highlight the importance of feeling a sense of community with other users. Secondly, the pilot studies (Chapters 4 and 5) included in this study conducted prior to the final experimental study revealed novel findings which were used to inform the final experiment. They demonstrated the divergence and inconsistency in psychological and physiological measures of mental well-being and highlighted the significance of triangulating measures with qualitative data. Comparison was also made between exposure to restorative environments through flat-screen exposure and VR, and it was concluded that VR as a research tool can provide a greater level of immersion. Finally, the main experimental study (Chapter 6) revealed that being in crowded UGS can be stressful and have a negative impact on perceived restorativeness. Additionally, viewing VR UGS can increase energy (after viewing a stressor), although for hedonic tone there was no evidence that this effect depended on the amount of people in the space. There appeared to be a trade-off in that busier spaces improved social connectedness and heightened feelings of energy but reduce perceived restorativeness, while less busy spaces promoted restoration but provided less opportunities for social connectedness or increased energy. There was some evidence of good convergent validity between measures as the findings for diastolic blood pressure, and almost heart rate (close to significance), supported the findings of self-reported stress. These convergent findings add to the literature in regard to the effects of crowding in UGS. Qualitative findings in this study also highlighted the benefits of solitude but noted feelings of vulnerability in empty spaces. Social connectedness was increased in environments with some people, particularly where there were a few but not too many. Continuing on from the focus on age in the first qualitative study (Chapter 3), this experiment (Chapter 6) also tested for age as a moderator and suggested that differences in the mental well-being benefits associated with different levels of crowdedness in UGS could be more pronounced for older populations.

7.3. Theoretical contributions

Chapter 2 of this thesis presented the literature review which introduced key theories underpinning how environments can be attentionally restorative (ART; Kaplan & Kaplan, 1989) and aid in stress recovery (SRT; Ulrich, 1983; Ulrich et al., 1991). The studies included in this thesis provide new evidence which provides a deeper understanding of the aspects of UGS which can be restorative and provide recovery from stress. How the studies have contributed to theory will be discussed next.

7.3.1. Urban greenspaces and restoration

The findings of this thesis can be discussed in relation to ART and SRT (Kaplan & Kaplan, 1989; Ulrich, 1983; Ulrich et al., 1991). A main contribution from the body of work in this thesis is the exploration of other people being present in an UGS and how this can impact perceived restorativeness. This was the focus on the VR experiment in Chapter 6 and was the only chapter to focus on perceived restorativeness as an outcome. A key finding from the study was that there appeared to be a trade-off between feeling invigorated (energised and socially connected) in an UGS, and restoration from stress. Feeling less stressed in the UGS can also be discussed in relation to SRT in providing support for the theory.

Participants reported increased feelings of perceived restorativeness when fewer people were present, however they also felt less socially connected. Likewise, when more people were present, participants felt more energised from the atmosphere of people being around and feeling more socially connected but perceived the space to be less restorative. This study has suggested that whilst an UGS with people being present can influence restorativeness in one way, but in a different way can also offer potentially health-enhancing psychophysiological outcomes like energy or feeling socially connected.

Furthermore, the components which make up ART (being away, extent, soft fascination, and compatibility) could be suggested as being quite rigid. The theory suggests that the four components contribute to a space being restorative. In addition to the social benefits which can be gained from a space, another key finding from the experiment in Chapter 6 was that what people need from a space to aid restoration varies over time. This adds another level of complexity beyond the four components to suggest variation within as well as between individuals. There is emphasis on the 'being away' dimension in the original theory of ART. The qualitative study findings (Chapter 3) align with this and found that individuals across all ages spoke about the importance of escaping into UGS which are large enough to do that, and also offer variation within the space. However, the findings in the final experimental study (Chapter 6) go beyond this to suggest that being away from people can also have a negative impact on feelings of social connectedness. It was concluded that other people being present in an UGS can be positive and beneficial for mental well-being. This was supported by both the quantitative subjective results, as well as the more in-depth qualitative outcomes in Chapter 6. Further research could look at the individual components of ART and whether there are components which are more sensitive to certain conditions (different amounts of people). An initial analysis of this is presented in [Appendix 28](#), and it is suggested that future research continues this exploration.

Effort has been made to go beyond a more conventional theoretical narrative of ART and SRT and build upon these perspectives (Hartig, 2021). This thesis has largely adhered to this conventional narrative and presented the included studies in the context of ART and SRT by introducing them in reviews of the literature and discussing the findings in relation to these underpinning theories. However, it is recognised that ART and SRT are focused on the individual and the environment and do not consider the social aspects of the space and how multiple people engage with environments and influence the benefits of natural spaces. Recent literature attempts to go beyond the more conventional theoretical narrative of ART and SRT and build upon these perspectives (Hartig, 2021). The final experiment (Chapter 6) presented in this thesis in particular can be discussed in relation to these more recent perspectives, which are outlined by Hartig (2021) and include two theories referred to as relational restoration theory (RRT) and collective restoration theory (CRT). These theories focus on how restorative experiences can be influenced by other people and that resources can be depleted at the level of a dyad or community instead of an individual. RRT proposes that social relationships in a dyad or small group can become strained and restored through exchanges within the dyad or group that allow distancing from demands and settings that enhance engagement. Whereas CRT posits that relational resources in a community can become strained and restored through institutional arrangements for shared activity. The findings from the qualitative study (Chapter 3) and the final experiment (Chapter 6) relate in particular to CRT. They demonstrate that people value sharing UGS with others and they feel more connected and energised when other people are present. These outcomes could reflect group relational resources being restored by institutional arrangements, of which this would reflect the provision of UGS that foster social conviviality.

7.3.2. Broader frameworks

The findings in this thesis can also be discussed in relation to the broader frameworks of nature and health (Hartig et al., 2014; Markevych et al., 2017; Nieuwenhuijsen et al., 2017). An important aspect of such frameworks which this thesis has addressed is the social aspect of being in nature and how this is linked to mental well-being outcomes. These frameworks include social contact or cohesion as an important mediator in the relationship between nature exposure and health and mental well-being, whereas this thesis has focused more on social connectedness as an outcome, and a sub-dimension of mental well-being.

Furthermore, these frameworks recognise numerous modifiers of the pathways from nature to health, including perceived safety. A consistent finding identified in the qualitative study in this thesis (Chapter 3) and the final experimental study (Chapter 6) was the topic of perceived safety in UGS. In the qualitative study, safety concerns were identified as a subtheme to the main theme which discussed practical needs for visiting UGS of all age groups. It encompassed feelings of safety during different times of the day, especially at night where there is a lack of lighting, and the presence of strangers which could cause conflict. In the qualitative interview part of the experimental study in Chapter 6, concern over safety in the virtual UGS was also raised in relation to feeling vulnerable when there were no other people around in the space. However, in the qualitative answers in pilot study 2 (Chapter 5), no participants discussed perceived safety. Additionally, these frameworks put a greater emphasis on qualities of natural environments which relate to size, amount, type, naturalness, or ecological quality. The findings in this thesis provide new contributions to these frameworks in that there should be more consideration of the social and relational qualities of these spaces in determining the type of contact people have with them and the resultant outcomes.

7.4. Methodological contributions

As well as contributing to theories which underpin the mental well-being benefits gained from natural environments like UGS, the body of work in this thesis also makes methodological contributions. Discussion of the multimethod nature of this thesis will be presented next, in addition to the contributions made to experimental research in regard to the use of subjective and objective measures of mental well-being and using VR as a research tool.

7.4.1. Multimethod approach

The body of work in this thesis adopted a multimethod approach by implementing both qualitative and quantitative methods. A first initial qualitative study was conducted, followed by a quantitative pilot study, a combined quantitative and qualitative pilot study, and then a final quantitative and qualitative experimental study. The methods of these studies developed over the course of the PhD with each study design informed by the previous. Chapter 6 was informed by Chapters 3-5. The qualitative nature of the first study (Chapter 3) allowed for a broad, yet detailed, exploration which was then used to narrow down a focus for a quantitative experimental study (Chapter 6) which would be able to

provide evidence for a cause-and-effect relationship with a high degree of control and rigour. The design of this experiment was informed by two pilot studies which demonstrated that simultaneous subjective and objective quantitative measures are recommended (Chapter 4) and that triangulation with a qualitative measure (Chapter 5) can bring even more strength and validity to the study design.

The methods adopted across the four studies in this thesis contribute to existing evidence in a couple of ways. Firstly, within environmental psychology, qualitative research on UGS and mental well-being has had less prominence (Ratcliffe et al., 2024). The qualitative study (Chapter 3) has therefore added a deeper and more complex understanding of interactions with UGS and how they are beneficial for different age groups. Secondly, previous experimental studies have rarely combined quantitative and qualitative methods in the same study design. Over the course of the experimental studies in this thesis, it was recognised that a qualitative measure at the end of the experiment would allow the participant to give context to their responses and provide a deeper understanding of their experience of the environmental stimuli.

This thesis demonstrates how multimethod research can be conducted and contribute to the field. It should be noted clearly here that monomethod research is not disregarded as it is appropriate for certain projects and contexts (Hunter & Brewer, 2015). However, this thesis demonstrates the strengths that multimethod research can have, when appropriate to the research question. By adopting a multimethod approach, this thesis has taken a more holistic approach to answering the overarching research questions. The gaps highlighted in the literature review (Chapter 2) which were investigated in this thesis included a need to focus on age, the use of VR as a research tool, and the social aspects of UGS in relation to mental well-being. These topics were complex to address, with each one needing a tailored approach, which led to the use of multiple methods.

7.4.2. Multiple measures of well-being

A main finding from this thesis was that psychological and physiological measures of mental well-being can show divergent results (Chapters 4 and 5) and convergent results (Chapter 6) when assessing the mental well-being benefits gained from UGS. This contributes methodologically to the field by demonstrating that both types of measures should be considered in order to provide a more comprehensive and holistic approach to mental well-being. This would lead to a deeper understanding of UGS and their impact on mental well-being, help with understanding causal pathways, and provide a fuller picture in terms of

outcomes. Psychological measures are subjective and can help in explaining how individuals perceive UGS and explain why spaces can be beneficial or not, whereas objective measures can show whether perceptions are aligned with bodily responses and observable physical benefits for mental well-being. Overall, the choice of a complementary set of psychological and physiological measures can influence the conclusions made depending on their convergence or divergence and researchers measuring stress especially should consider what part of the stress pathway they are interested in evidencing as well as the practicalities of administering the necessary equipment and dealing with noise the data.

The experimental studies included in the body of work developed over time, and the final study included a qualitative measure in addition to subjective and objective measures, which allowed for triangulation. As demonstrated by the studies in this thesis, including a qualitative measure yielded more detail which aided interpretation of the subjective and objective measures, mitigating the risk of misinterpretation if using only one type of measure. Whilst this approach was more time consuming and resulted in participants dedicating more time to taking part in the research, the combination of measures ultimately allows for more depth in the data which can lead to better informed recommendations for policy and practice.

A reflection is also made here regarding the subjective measures which were used across the empirical studies in this thesis. The UWIST MACL was used across the studies to measure mental well-being. The shortened version of this scale was used in the two pilot studies (Chapter 4 – reported hedonic tone (2 items) and stress (2 items), and Chapter 5 – reported stress only (2 items)) due to them being pilot studies with time intensive physiological measures (EEG). The final experiment (Chapter 6) then had more time for the optimal measures to be used (and having removed EEG measurements), so the longer version of the UWIST MACL was included, which had an extra dimension for energy. This was particularly relevant to the social component of the study (e.g., the presence and energy of people).

7.4.3. VR as a research tool

This thesis has contributed methodologically by demonstrating that VR can be used as an immersive research tool when exploring mental well-being and the benefits gained from UGS. VR can be used to create an immersive environment which allows for a high level of control and manipulation of stimuli and shows significant effects on mental well-being outcomes (Chapters 5 and 6). VR can be feasible in experiments, similar to the ones

presented in this thesis, and can confer psychophysiological benefits when presenting nature stimuli in this way. This support for VR as a research tool is also consistent with other fields of research such as studies which have looked at using it as a tool for navigating buildings (Feng et al., 2022), communication for people with communication disability (Bryant et al., 2020), crime research (van Gelder et al., 2014), and in education to enhance experiential learning (Asad et al., 2021). Additionally, as shown in Chapters 4 and 5, VR can provide a more realistic experience and facilitate presence and immersion in stimuli than comparable methods, such as flat-screen.

It is also noted here that the length of exposure to the environmental stimuli changed across the empirical studies in this thesis. The smaller pilot studies (Chapter 4 and 5) which involved lengthy set-up time for EEG measurement had shorter exposures to the environments. In pilot study 1 (Chapter 4), exposure length for each environment was 4 mins. This exposure time was then reduced to 2 mins per environment in pilot study 2 (Chapter 5) due to the piloting of VR and being cautious of the risk of potential cybersickness. This pilot study showed no effects of cybersickness in participants and so a longer exposure time was adopted in the final experimental study (Chapter 6), as well as having more time to design an optimal study which did not involve long equipment set-ups, such as EEG measurement.

7.5. Strengths and limitations

The body of work in this thesis has several strengths and limitations which are reflected on here. Firstly, all studies conducted as part of this thesis may be limited by unrepresentative samples. Each study recruited in a way that was appropriate for the individual aims and research questions. For example, focusing on intergenerational mental well-being (Chapter 3) meant that recruiting across multiple age groups was the determining factor for the recruitment strategy. Whilst this was successful, participants lacked diversity in other demographic variables such as ethnicity and gender. Across all studies, the majority of participants were white women. This sampling bias may have influenced the reported findings, such as why some of the studies in this thesis identified themes around perceived safety in UGS, as previous literature has shown that this is a prominent issue for women (Barker et al., 2023). Furthermore, the findings of the studies may not accurately represent the views of other ethnic groups and underserved communities which has previously been shown to be an important factor in relation to UGS and health (Roe et al., 2016). This is particularly important knowing that these populations generally have access to smaller and

worse quality greenspaces (Rigolon, 2016; Schüle et al., 2019). There was only scope in this body of work to focus on one demographic factor, which was age, so future research is warranted which looks at other factors including ethnicity and gender. Furthermore, the sample of participants recruited for the studies in this thesis may have also been biased in that they represented individuals who volunteer to take part in studies and may have an interest in the research and enjoy going to natural environments. Despite efforts during recruitment to advertise the studies through various avenues to reach many audiences (e.g., emails, word of mouth, posters etc), participants voluntarily came forward to take part which could be biased. Despite the limitation mentioned, the recruitment methods adopted in some of the studies conducted in this thesis did attract community based participants and non-student samples, which is an advance on typical environmental psychology research.

Furthermore, a limitation of the body of work in this thesis relates to bias. Firstly, there may have been measurement bias and this could have influenced the research. All of the studies were conducted with efforts to ensure rigour. For the experimental studies, this was done by using validated scales, trying to minimise confounding variables, and using multiple measures to assess convergent and discriminant validity. For the qualitative aspects of this thesis, this was done by designing interview schedules which did not contain leading questions and by being reflexive about my role as a researcher. However, bias may also have been introduced by the researcher or the participants. During the qualitative components of this thesis, as the interviewer, I may have influenced the data with my own biases (preferring natural environments over urban ones, preferring to be alone in spaces, and enjoying technology such as VR). Whilst there is a degree of acceptance of researcher bias in regard to qualitative research, steps were taken to try and avoid influence. These involved developing open-ended questions which were reviewed by supervisors and being aware during building rapport with participants not to provide details of my personal preferences towards environments or any expected research findings. Participants were reassured prior to all studies that there were no right or wrong answers to encourage honesty and avoid social desirability bias. Moreover, the experimental studies were quite long and involved which may have led to participant fatigue and the temptation to provide inaccurate or socially desirable answers so to finish the study more quickly. But efforts were made to avoid fatigue and participants in all studies were allowed breaks at any time.

Another limitation across the body of work, particularly in relation to the experimental studies (Chapters 4,5,6), concerns the aspect of weather which was identified as a consistent theme and may have influenced the findings. Firstly, all of the environmental stimuli used in the experimental studies presented environments on a sunny, clear day when the weather was pleasant, and it was during daytime hours. This decision was made for each of the stimuli so to act as a baseline and not allow bad weather or darkness in an environment to influence the results. However, this may have worked opposingly in that responses were inflated due to the good weather during the daytime. In the final experiment in Chapter 6, numerous participants commented on the nice blue sky and sunny weather despite not being asked directly about it. Weather was also brought up as a sub-theme in the qualitative study (Chapter 3) whereby participants discussed their preference for visiting UGS on sunny days, although bad weather was not necessarily considered a deterrent. Previous research has looked at ephemeral phenomena and demonstrated its moderating effect on ratings of urban and natural environments (Smalley & White, 2023), and so perhaps here, there could have been an influential effect on the results. The included studies could therefore be criticised for continuing a trend of only examining environmental stimuli under clement weather conditions. Overall, future experimental studies should be considerate to the weather conditions in stimuli and how it could influence subsequent findings.

A consideration of this thesis which limits the generalisability of the findings presented is the primary focus on the urban aspects of UGS and the definition adopted in the thesis. The aim was to focus on greenspaces which are found in urban areas and which can combat the negative effects of urban living, therefore UGS were the specific area of interest. Knowing the considerable amount of the global, and UK, population living in urban areas, this was an important type of space to focus on. The definitions of nature and greenspace are broad and debated and used inconsistently in the literature (Taylor & Hochuli, 2017), and so a strength of this thesis was in clearly defining the term used and focusing on one type of space throughout the body of work. Keeping a narrow focus can lead to more specific policy and practice recommendations, which are discussed further in section 7.7. However, this also restricts the application of these findings to only UGS and excludes the wider natural ecosystem and context. Furthermore, aspects which this thesis did not cover include private areas of UGS, which have also been found to be beneficial for mental well-being but require further research (Collins et al., 2023; Howarth et al., 2020). For example, private gardens account for a large proportion of urban land cover but were covered by the scope of this

thesis (Hanson et al., 2021). Additionally, the focus on UGS in this thesis was also ethnocentric and findings generated here are unlikely to be transferable to countries with vastly different urban landscapes and planning practices.

7.6. Future research recommendations

In order to extend knowledge beyond this thesis, several recommendations for future research are presented next. These recommendations are informed by the findings of the studies in this thesis as well as topics which were beyond the scope of the thesis and warrant further exploration.

7.6.1. Extending qualitative findings

A recommendation for future research is to explore the three remaining themes which were identified in the qualitative study presented in Chapter 3. There was only scope in this thesis to carry forward one theme from the qualitative study to inform the topic focus of the final experimental study and this was chosen to be the theme, 'sharing a space with others'. The final experiment then adopted a narrower focus on the social aspects of UGS and investigated how other people being present can have an impact. The other three themes identified in the study were: 'UGS provide a sense of escape' with the sub-themes 'spaces need to be big enough' and 'spaces within a space', 'Practical needs for visiting UGS' with the sub-themes 'spaces need to be accessible', 'weather dependency' and 'safety concerns', and 'Seasonal sensory components'. All of these themes were identified as being important for users of UGS across all age groups. Future research should continue to take an intergenerational approach and focus specifically on these themes. This would extend the intergenerational perspective of UGS and the dynamics across age groups, which is currently lacking in the field. Future experimental research could be conducted manipulating each of these themes. For example, with weather, there has been some comparable research already which has looked at ephemeral meteorological phenomena (Smalley & White, 2023).

7.6.2. Barriers and non-users of urban greenspaces

Chapter 3 focused solely on users of UGS due to the need to speak to people who had experience of visiting the spaces and knowing what it is about them that they like and dislike. The aim of this study could not have been addressed if participants were not familiar with UGS and did not regularly use them. So, for the purpose of this study, the decision was justified. However, participation in experimental studies, as discussed in section 7.5, was

also often limited to more frequent UGS visitors. However, it is recognised here that it is also essential to speak to individuals who do not use UGS at all, in order to understand how barriers to access could be reduced (Boyd et al., 2018). Whilst this is a more difficult cohort to find and recruit to participate in research on this topic, it is arguably more important than researching people who already visit UGS, because there is even greater scope to improve mental well-being outcomes if barriers to use can be overcome through research. A study conducted across 33 European countries has begun to address this need and suggested that more research needs to focus on non-users of UGS (Laszkiewicz et al., 2023). The study involved a survey which found that participants (N = 10,391) reported key limiting factors to UGS use was due to lack of time and interest and being a long distance from where they live (Laszkiewicz et al., 2023).

7.6.3. Age-inclusive research

Age was one of the focuses of the research included in this thesis and the literature review conducted in Chapter 3 identified that there is a lack of intergenerational evidence in the field and few studies have included participants from a wide range of ages (Spano et al., 2023). This is problematic knowing that UGS are used by and can benefit all age groups, and so research evidence should reflect all ages. The main focus of the first qualitative study (Chapter 3) was to address this gap head-on and interview participants across multiple age groups about the properties of UGS which they find beneficial for their mental well-being. The study revealed that there are numerous similarities across age groups and emphasised the need for future research to take a similar approach. The final experiment in the thesis recruited participants across a wider range of ages, continuing an age-inclusive approach to research, although this did prove difficult and emphasised the importance of tailored recruitment to be effective. Age was considered in moderation analyses which showed that the overall findings were more pronounced for middle-to-older aged participants which provides support for the need to study age-specific populations independently within the same studies. Whilst the research in this thesis has made an effort to consider a wide range of ages, this is only a start which future research should continue. Recruiting participants across a range of age groups can be challenging due to the need for multiple recruitment strategies, consideration of ethical requirements needed for different age groups, and developing good rapport with different age groups. However, more intergenerational research would provide a strong base from which practitioners and policy-makers can design and implement UGS which are beneficial for multiple age groups (Nelischer & Loukaitou-Sideris, 2023).

Moreover, as research in the field continues to expand (e.g., nature exposure impacts on body image (Swami, 2024)), and research begins to suggest that it is not just about time in nature but rather ‘meaningful moments’ in nature (Richardson et al., 2021), there is an ongoing need for further research to unpick the complex pathways which connect exposure to nature and mental well-being. Beyond consideration of connectedness to nature as a control variable in the final experiment (Chapter 6), this thesis necessarily overlooked the influence of more deeper or meaningful relationships people hold with nature and how connectedness to nature could be a strong moderator of the mental well-being benefits of exposure to UGS (Fleury-Bahi et al., 2023).

7.7. Research applications

The research conducted in this thesis has important applications for practice and policies relating to UGS and how they can be better designed for all age groups and what people need at different times. Additionally, the application of VR as a tool for designing and testing spaces prior to implementation will be discussed.

7.7.1. Urban greenspaces for all

An important take-home message from this thesis is that age is an important factor which needs to be considered in both future research and in regard to practice and policy. More policies are called for which focus specifically on age (e.g., policies about age-inclusive spaces), and evidence in this thesis supports this call (Loukaitou-Sideris & Sideris, 2009; Rigolon et al., 2024). Whilst an ideal recommendation for practice and policy would be to provide more greenspaces within urban areas so that there is more space to accommodate everyone’s needs, space provision and financial budgets prevent this. Therefore, a more realistic and practical recommendation here instead would be to promote the redesign and development of UGS in a community-led way, incorporating research evidence and the views of users of multiple age groups (Sundevall & Jansson, 2020). This would ensure that UGS are inclusive for a range of ages. It could also lead to a sense of ownership and therefore better kept spaces, and ultimately contribute to mental well-being benefits for a wider range of people (Caperon et al., 2022). Previous approaches have involved age-friendly and child-friendly cities, however these tend to lead to a focus on younger and older people rather than all age groups, and there is need to think about all age groups collectively (Brown et al., 2019; Fitzgerald & Caro, 2014; Roe & McCay, 2021). Evidence across the globe promotes intergenerational public space design and planning and encourages creating public spaces that appeal to diverse ages, foster interaction and

engagement between different age groups, and can improve individual health and wellbeing (Biggs & Carr, 2016; Cushing & van Vliet, 2016; Nelischer et al., 2024; Nelischer & Loukaitou-Sideris, 2023).

As well as redesigning UGS with multiple ages in mind, UGS can also be thought of as dynamic spaces which cater for different situations as needed. A novel finding from the final experimental study (Chapter 6) discussed the concept of conditionality and that what people want from an UGS can be conditional on how people feel or what they need at that moment in time. This was discussed in relation to other people being present in an UGS but can be applied more generally. Making sure that UGS have multiple components so that they can cater for different situations (and different people) is necessary. For example, it is recommended to include areas in a space which can be for socialising but also design parts of the space suitable for solitude and escaping from crowded 'hotspots' (Lafrenz, 2022). Additionally, adolescents also want their own space within an UGS.

7.7.2. VR as a tool for design

The findings in this thesis support VR as a being a reliable and immersive research tool, whereby participants were shown environmental stimuli through a VR headset (Chapters 5 and 6). VR enabled the researcher to design a specific space which fitted the needs of the research questions and aims. An application of VR for practice could be its potential to be used as an effective tool for designing UGS before committing to real world development. Current research supports that UGS designs in VR can be transferred into real-world designs (Liang et al., 2024). The applications of VR are interdisciplinary in that the 3D design capabilities could prove useful for landscape architects and urban planners in being able to map out an immersive virtual space and identify problems without consequences to time and cost (Portman et al., 2015). The tool could also be used collaboratively with stakeholders and community members of different ages (and other characteristics) to aid in redesigning UGS. A more user-centred design approach is recommended here whereby user feedback can inform the decisions made regarding the UGS redesigns (Vassiljev et al., 2020).

7.7.3. Virtual nature applications

Overall, whilst this thesis provides support for VR being used as an immersive research tool in future research studies, it does not promote VR being used as an alternative to visiting real environments. In parallel though, it is recognised that VR can be useful if real exposure is not possible. For example, studies have begun to assess the use of VR exposure to green

or natural environments in clinical settings such as hospitals and hospices (White et al., 2018), for populations with limited mobility or disabilities (Kalantari et al., 2022), and people in isolated places such as prisons (Nadkarni et al., 2021). There calls for a wider movement to bring more nature indoors in areas such as in the workplace and clinical settings including hospitals and care homes. Biophilic workspace design (increasing connection to nature through direct and indirect contact, e.g., plants, wallpapers of nature) can increase energy in employees (Klotz & Bolino, 2021), enhance job performance (Sadick & Kamardeen, 2020), and stress can be lowered in a multi-sensory biophilic designed workspace (Aristizabal et al., 2021). Employees taking breaks at work in natural environments report improved creativity (Atchley et al., 2012), satisfaction with work (R. Kaplan et al., 1996), and reduced stress (Largo-Wight et al., 2017). Work breaks involving exposure to virtual nature have also been found to be beneficial in restoring stress (Ojala et al., 2022) and could be promoted where access to real greenspace is not easily accessible in a break.

As well as the workplace, including nature in clinical settings can also prove beneficial for patients. Whilst the body of work in this thesis did not focus on and include the clinical aspects of nature exposure, the applications are recognised here. Most notably, one of Ulrich's earliest studies which informed SRT showed that patients viewing a natural setting from their hospital window had shorter stays in hospital compared to patients with a view of a brick wall (Ulrich, 1984). Additionally, including plants in hospital waiting rooms can have the potential to reduce patients' feelings of stress (Beukeboom et al., 2012). Also including foliage plants and flower arrangements on hospital wards can have positive effects such as reducing stress, reducing stays and increasing optimism (Khan et al., 2016). Viewing calming nature films whilst undergoing routine procedures has also been found to decrease cortisol, increase prolactin, and enhanced oxygen saturation (Sjölander et al., 2019). A recent study combining the use of both real nature (plant walls) and digital nature (digital nature wall) in a healthcare setting, found that they can have a beneficial effect on emotional well-being in reducing negative emotions and increasing positive ones (Jung et al., 2023). Digital nature has also been implemented with older adults in care homes who have limited mobility and where visits to real nature are practically difficult (van Houwelingen-Snippe et al., 2023a, 2023b). Potential for enhancing social well-being, promoting skills development and social interaction is reported by these studies.

7.8. Reflections

Across the duration of this PhD, some reflections can be made in relation to the experience of having conducted an alternative format PhD, which spans several disciplines. It is noted here that the work presented in this thesis has also been disseminated at several local and international conferences and more detail of this is provided in [Appendix 32](#). Additionally, the large undertaking of creating experimental stimuli for use in VR brings numerous points of reflection. Reflections will be made next which encompass these topics.

7.8.1. Alternative format PhD

As this thesis was comprised of both traditional and chapters composed of peer-reviewed journal publications (Chapters 3,4,5), I reflect here on having produced an alternative format thesis. Alternative format theses are becoming increasingly popular in UK and international institutions and allow for a flexible approach to the thesis (Mason, 2018; Robinson, 2023). Several strengths and challenges which came with conducting the thesis in this way will now be reflected upon.

A major strength of conducting a PhD by alternative format is the experience that has been gained from writing publications and the overall publication process. From producing publications, it has meant that the research findings and new knowledge are visible in the academic community and can be recognised and used by other scholars in the field. The included publications have been subject to peer-review which has strengthened the research output as a whole and confirmed the content to be of publishable standard. For example, with the qualitative study (Chapter 3), reviewers made suggestions which involved incorporating more critically evaluative points into the articles discussion (e.g., more limitations of the research). This, along with reviewer comments on the remaining publications, has led to a deep level of reflexivity of the included studies. I have developed strong research skills from experiencing the publication process, including improved critical evaluation and designing projects for the generation of new knowledge which can advance research in the field. This has led to my development as a researcher, learning research skills, and in understanding the requirements and expectations for a research-led career. Overall, this format has led to there being a focus on satisfying the peer-review process for each publication included in this thesis (Chapters 3,4,5). As well as strengths, there have also been challenges which have accompanied the alternative format process. An initial challenge was surrounding the novelty of alternative format which has meant that there are

a lack of resources, literature, and examples for alternative format PhDs. Some general resources exist such as review articles, blog posts and podcasts, however these are recent and overall, the format is very novel at UWE. Another challenge emerged in relation to the writing style adopted for the included publications. Writing publishable content for specific journals required being concise, restrictive, and direct due to the pre-determined word counts set by the journals. This therefore led to structuring challenges for the thesis so to include the published contents as they are but whilst also demonstrating an appropriate amount of depth and detail in the thesis. As well as the writing style, challenges also emerged during the publication process. The duration of the publication process resulted in long delays in receiving reviewer feedback and then editing publications to address feedback. Whilst overall this feedback was invaluable in improving the publications, this led to an increased feeling of uncertainty.

7.8.2. Designing VR environments

A central aspect of this thesis was the use of VR as a research tool, which was utilised in Chapters 5 and 6. Two different approaches were used. Firstly, 360-degree footage shown through a VR HMD was utilised in Chapter 5 whereby 360-degree environments were filmed at various locations (by a VR expert) with a 360-degree camera, edited and shown to participants through a headset. The final experiment (Chapter 6) then took a different approach and involved designing computer-generated virtual environments (CGI-VR) rather than pre-filmed footage or fully pre-made environments. As with the pilot study presented in Chapter 5, the environments were shown using a VR HMD. This decision to create the environments from scratch was made due to the amount of control this would allow over the stimuli creation, the ability to fully align the stimuli with the research aims, and because it is something that few experiments in the field have undertaken. Whilst there were several benefits that came with this decision, there were also several challenges which occurred during the process.

Firstly, I had no experience with creating VR environments before or any knowledge of the software and process involved, so it was difficult to predict initially how long the process would take, and ultimately this was underestimated. The process involved a steep learning curve of the software needed for VR design, which was Unity (Unity Technologies, 2024). This was achieved with numerous self-taught modules, webinars, and tutorials which explained several skills such as environment design and the user interface, 360-degree capabilities and camera angles, lighting and resolution, textures and layering, and sound.

Some time was saved in that the individual elements built into the environment were ‘prefabs’ which were designs, or ‘assets’, which could be purchased or were obtainable for free from the Unity Asset store or the Sketchfab Store. For example, individual trees, benches, lampposts, and people were pre-designed elements which were brought together to create a novel environment. Challenges also arose in regard to technical difficulties. A considerable amount of time was spent troubleshooting such as adjusting lighting and the resolution of the environments, the volume of the auditory stimuli coming from the HMD, and the placement of the camera rig within the environment.

Despite the challenges that arose, the decision to design and create the environments from scratch greatly enhanced the study in Chapter 6 and allowed for an environment which directly addressed the research aims and could examine the effect of interest. This approach to stimuli creation is a novel addition to the research field and something that future VR research studies should consider.

7.8.3. Ethics of VR

A reflection can be made here after a striking response from a participant who took part in the experimental study conducted in Chapter 6. They commented after the VR exposure that:

“I was in a different world and could have been there all day. I don’t need to go to the park today now!”

Knowing the effectiveness of VR as a research tool, it might be questioned whether VR can be used instead of real world exposure. Previous studies have shown that VR exposure to natural environments can yield similar psychological and physiological responses to real exposure in these environments (Browning et al., 2020; Liang et al., 2024; Nukarinen et al., 2020). VR could be arguably beneficial in taking away the risks and negative associations with real environments, such as allergies (e.g., pollen), interpersonal conflicts, fears (e.g., agoraphobia), and extreme temperatures. However, there are certain aspects which VR is not able to fully provide. For example, there is a wide range of physical benefits to being outside. Physical activity is a key reason for visiting UGS (green exercise) and is something that the space allows for, such as running, playing sports individually or with other people, and using play equipment (Akpınar, 2019; Lahart et al., 2019; Machado et al., 2016). The benefits of exercise in nature is well-supported (Barton et al., 2016; Pretty et al., 2005;

Rogerson et al., 2020) and there is a large amount of evidence demonstrating the benefits of walking in natural environments (Ma et al., 2024; Olafsdottir et al., 2020; Sudimac et al., 2022; Trammell et al., 2024). Interestingly, research has also found VR to be a tool that can promote green exercise and encourage participants to visit the real space which they see in a simulation (Calogiuri et al., 2022).

In addition to physical activity, having real conversations with real people, or bumping into friends or neighbours on a walk through a park, is something which is difficult to replicate in VR. Social interaction is a key benefit which can be gained from physically visiting an UGS and whilst virtual people like avatars can be created, replicating real human interactions is difficult. Visiting a park in real life may also take up a considerable amount of time, for example an hour, and this amount of time in VR would not be as advisable due to the risk of cybersickness and eye strain, although there is a lack of research which has looked at the long-term effects of VR usage. Additionally, VR is unable to replicate some sensory aspects of being outside in a real environment. For example, the haptic feedback of feeling the temperature on your skin, the feel of the wind, or feeling exposure from the sunlight (White et al., 2018).

Moreover, a wider discussion can be had around the use of VR and virtual nature as contributing to the 'extinction of experience'. The extinction of experience was first coined 30 years ago and describes humans ongoing disconnect from nature (Pyle, 1993). Whilst there is not one clear cause, triggers are thought to include increasing numbers of people living in urban areas, the advancement of technology, and a more sedentary lifestyle (Soga & Gaston, 2016). Living in urban areas can lead to a loss of opportunity to experience nature due to the fewer natural areas around and having reduced access. Additionally, loss of orientation and interest and wanting to engage with nature is a crucial element to the extinction of experience (Soga & Gaston, 2016). The use of VR as an alternative to experiencing nature for the general population is not encouraged here, but it could be helpful for certain populations or as a complementary aid to mental well-being (e.g., on a break from work) or as a tool for managing stress.

7.9. Overall conclusions

This thesis took a holistic, multimethod approach to the topic of UGS and mental well-being and aimed to explore which specific properties of UGS are beneficial and whether this is the same across different ages, how new technology, specifically VR, can be used as a research tool for exposure, and taking a narrower focus on the social aspect of UGS to see how

crowding can impact the experience of UGS. A key conclusion made in this thesis is the importance of considering age, which was explored in this body of work. This thesis highlights the importance of taking an intergenerational approach to the topic and focusing more inclusively by considering multiple age groups in research. The first qualitative study (Chapter 3) highlighted the many similarities between age groups, and the final experimental study (Chapter 6) suggested that effects are more pronounced in middle-to-older aged adults. Methodological conclusions are made in this thesis which are that mental well-being in research needs to be measured using multiple measures (subjective, objective, and qualitative) in order to gain a full understanding and avoid misleading conclusions. Another main methodological conclusion here is the feasibility and acceptability of VR as a research tool in the field. This powerful technology can be used for designing spaces to suit the need of experimental research to isolate individual effects. Providing there is time and cost allowance, building immersive environments specific for a study's research question are possible by using VR. This thesis also makes theoretical contributions by providing experimental evidence which goes beyond the conventional narrative of restoration in the field. A prominent finding from the final experimental study in this thesis suggests a trade-off between restoration from stress and feeling invigorated and energised (socially connected) from a space where other people are present. Overall, by taking a multimethod approach, the conclusions made in this thesis are supported by both quantitative and qualitative evidence which provide a more holistic understanding of the topic. This thesis provides evidence to inform robust experimental designs in future research aiming to understand the mental well-being benefits of being in UGS, and how these may be affected by factors, such as age.

References

- Abella, J. L., Fruttero, A., Taş, E. O., & Taj, U. (2020). Urban Design, Public Spaces, and Social Cohesion. World Bank Group.
- Abraham, A., Sommerhalder, K., & Abel, T. (2010). Landscape and well-being: A scoping study on the health-promoting impact of outdoor environments. *International Journal of Public Health*, 55(1), 59–69. <https://doi.org/10.1007/s00038-009-0069-z>
- Acocella, I. (2012). The focus groups in social research: Advantages and disadvantages. *Quality & Quantity*, 46(4), 1125–1136. <https://doi.org/10.1007/s11135-011-9600-4>
- Adesemowo, A. K. (2023). IDADA: Towards a multimethod methodological framework for PhD by publication underpinned by critical realism. *Humanities and Social Sciences Communications*, 10(1), 1–16. <https://doi.org/10.1057/s41599-023-02498-w>
- Adli, M. (2011). Urban stress and mental health (Cities, Health and Well-Being). https://lsecities.net/wp-content/uploads/2011/11/2011_chw_4030_Adli.pdf
- Aggio, D., Smith, L., Fisher, A., & Hamer, M. (2015). Mothers' perceived proximity to green space is associated with TV viewing time in children: The Growing Up in Scotland study. *Preventive Medicine*, 70, 46–49. <https://doi.org/10.1016/j.ypmed.2014.11.018>
- Akpınar, A. (2019). Green Exercise: How Are Characteristics of Urban Green Spaces Associated with Adolescents' Physical Activity and Health? *International Journal of Environmental Research and Public Health*, 16(21), Article 21. <https://doi.org/10.3390/ijerph16214281>
- Allen, A. P., Kennedy, P. J., Cryan, J. F., Dinan, T. G., & Clarke, G. (2014). Biological and psychological markers of stress in humans: Focus on the Trier Social Stress Test. *Neuroscience and Biobehavioral Reviews*, 38, 94–124. <https://doi.org/10.1016/j.neubiorev.2013.11.005>
- Allender, S., Wickramasinghe, K., Goldacre, M., Matthews, D., & Katulanda, P. (2011). Quantifying Urbanization as a Risk Factor for Noncommunicable Disease. *Journal of Urban Health : Bulletin of the New York Academy of Medicine*, 88(5), 906–918. <https://doi.org/10.1007/s11524-011-9586-1>

- Altman, B., & Bernstein, A. (Eds.). (2008). *Disability and health in the United States, 2001-2005*. Dept. of Health and Human Services, Centers for Disease Control and Prevention, National Center for Health Statistics.
- Alvarsson, J. J., Wiens, S., & Nilsson, M. E. (2010). Stress Recovery during Exposure to Nature Sound and Environmental Noise. *International Journal of Environmental Research and Public Health*, 7(3), Article 3. <https://doi.org/10.3390/ijerph7031036>
- Alves, N. T., Fukushima, S. S., & Aznar-Casanova, J. A. (2008). Models of brain asymmetry in emotional processing. *Psychology & Neuroscience*, 1, 63–66. <https://doi.org/10.1590/S1983-32882008000100010>
- Ambrey, C. L., Fleming, C. M., & Manning, M. (2014). Perception or Reality, What Matters Most When it Comes to Crime in Your Neighbourhood? *Social Indicators Research*, 119(2), 877–896. <https://doi.org/10.1007/s11205-013-0521-6>
- Anderson, A. P., Mayer, M. D., Fellows, A. M., Cowan, D. R., Hegel, M. T., & Buckey, J. C. (2017). Relaxation with Immersive Natural Scenes Presented Using Virtual Reality. *Aerospace Medicine and Human Performance*, 88(6), 520–526. <https://doi.org/10.3357/AMHP.4747.2017>
- Andringa, T. C., Weber, M., Payne, S., Krijnders, D., Dixon, M., Linden, R., Kock, E., & Lanser, J. (2013). Positioning soundscape research and management. *The Journal of the Acoustical Society of America*, 134, 2739–2747. <https://doi.org/10.1121/1.4819248>
- Angel, S., Parent, J., Civco, D. L., Blei, A., & Potere, D. (2011). The dimensions of global urban expansion: Estimates and projections for all countries, 2000–2050. *Progress in Planning*, 75(2), 53–107. <https://doi.org/10.1016/j.progress.2011.04.001>
- Angner, E. (2011). The Evolution of Eupathics: The Historical Roots of Subjective Measures of Well-Being (SSRN Scholarly Paper 799166). <https://papers.ssrn.com/abstract=799166>
- Annerstedt, M., Jönsson, P., Wallergård, M., Johansson, G., Karlson, B., Grahn, P., Hansen, Å. M., & Währborg, P. (2013). Inducing physiological stress recovery with sounds of nature in a virtual reality forest—Results from a pilot study. *Physiology & Behavior*, 118, 240–250. <https://doi.org/10.1016/j.physbeh.2013.05.023>
- Appleton, J. (1975). *The experience of landscape*. The Experience of Landscape. <https://cir.nii.ac.jp/crid/1130000797742598528>

- Aristizabal, S., Byun, K., Porter, P., Clements, N., Campanella, C., Li, L., Mullan, A., Ly, S., Senerat, A., Nenadic, I. Z., Browning, W. D., Loftness, V., & Bauer, B. (2021). Biophilic office design: Exploring the impact of a multisensory approach on human well-being. *Journal of Environmental Psychology*, 77, 101682. <https://doi.org/10.1016/j.jenvp.2021.101682>
- Arnberger, A. (2012). Urban Densification and Recreational Quality of Public Urban Green Spaces—A Viennese Case Study. *Sustainability*, 4(4), Article 4. <https://doi.org/10.3390/su4040703>
- Arnberger, A., & Eder, R. (2015). Are urban visitors' general preferences for green-spaces similar to their preferences when seeking stress relief? *Urban Forestry & Urban Greening*, 14(4), 872–882. <https://doi.org/10.1016/j.ufug.2015.07.005>
- Arnett, J. J. (2008). The neglected 95%: Why American psychology needs to become less American. *American Psychologist*, 63(7), 602–614. <https://doi.org/10.1037/0003-066X.63.7.602>
- Arpaia, P., D'Errico, G., De Paolis, L. T., Moccaldi, N., & Nuccetelli, F. (2022). A Narrative Review of Mindfulness-Based Interventions Using Virtual Reality. *Mindfulness*, 13(3), 556–571. <https://doi.org/10.1007/s12671-021-01783-6>
- Artmann, M., Chen, X., Iojă, C., Hof, A., Onose, D., Ponizy, L., Lamovšek, A. Z., & Breuste, J. (2017). The role of urban green spaces in care facilities for elderly people across European cities. *Urban Forestry & Urban Greening*, 27, 203–213. <https://doi.org/10.1016/j.ufug.2017.08.007>
- Arvidsen, J., Schmidt, T., Præstholt, S., Andkjær, S., Olafsson, A. S., Nielsen, J. V., & Schipperijn, J. (2022). Demographic, social, and environmental factors predicting Danish children's greenspace use. *Urban Forestry & Urban Greening*, 69, 127487. <https://doi.org/10.1016/j.ufug.2022.127487>
- Asad, M. M., Naz, A., Churi, P., & Tahanzadeh, M. M. (2021). Virtual Reality as Pedagogical Tool to Enhance Experiential Learning: A Systematic Literature Review. *Education Research International*, 2021(1), 7061623. <https://doi.org/10.1155/2021/7061623>
- Astell-Burt, T., Hartig, T., Putra, I. G. N. E., Walsan, R., Dendup, T., & Feng, X. (2022). Green space and loneliness: A systematic review with theoretical and methodological guidance for future research. *Science of The Total Environment*, 847, 157521. <https://doi.org/10.1016/j.scitotenv.2022.157521>

- Atchley, R. A., Strayer, D. L., & Atchley, P. (2012). Creativity in the Wild: Improving Creative Reasoning through Immersion in Natural Settings. *PLoS ONE*, 7(12), e51474. <https://doi.org/10.1371/journal.pone.0051474>
- Ayala-Azcárraga, C., Diaz, D., & Zambrano, L. (2019). Characteristics of urban parks and their relation to user well-being. *Landscape and Urban Planning*, 189, 27–35. <https://doi.org/10.1016/j.landurbplan.2019.04.005>
- Bagheri, M., & Power, S. D. (2020). EEG-based detection of mental workload level and stress: The effect of variation in each state on classification of the other. *Journal of Neural Engineering*, 17(5), 056015. <https://doi.org/10.1088/1741-2552/abbc27>
- Bambra, C., Gibson, M., Sowden, A., Wright, K., Whitehead, M., & Petticrew, M. (2010). Tackling the wider social determinants of health and health inequalities: Evidence from systematic reviews. *Journal of Epidemiology & Community Health*, 64(4), 284–291. <https://doi.org/10.1136/jech.2008.082743>
- Barker, A., Holmes, G., Alam, R., Cape-Davenport, L., Osei-Appiah, S., & Warrington Brown, S. (2022). What Makes a Park Feel Safe or Unsafe? The views of women, girls and professionals in West Yorkshire. University of Leeds. 10.48785/100/108
- Barker, A., Warrington Brown, S., Forman, H., McClean, C., Walker, S., & Warrington Brown, S. (2023). Designing neighbourhood parks to foster women and girls' sense of safety. *Town and Country Planning*, 92(3), Article 3.
- Barry, R. J., Clarke, A. R., Johnstone, S. J., Magee, C. A., & Rushby, J. A. (2007). EEG differences between eyes-closed and eyes-open resting conditions. *Clinical Neurophysiology*, 118(12), 2765–2773. <https://doi.org/10.1016/j.clinph.2007.07.028>
- Barton, H., & Grant, M. (2006). A health map for the local human habitat. *The Journal of the Royal Society for the Promotion of Health*, 126, 252–253. <https://doi.org/10.1177/1466424006070466>
- Barton, J., Bragg, R., Wood, C., & Pretty, J. (Eds.). (2016). *Green exercise: Linking nature, health and well-being*. Routledge, Taylor & Francis Group, Earthscan from Routledge.
- Becker, A. E., & Kleinman, A. (2013). Mental health and the global agenda. *The New England Journal of Medicine*, 369(14), 1380–1381. <https://doi.org/10.1056/NEJMc1309899>

- Bell, I. H., Nicholas, J., Alvarez-Jimenez, M., Thompson, A., & Valmaggia, L. (2020). Virtual reality as a clinical tool in mental health research and practice. *Dialogues in Clinical Neuroscience*, 22(2), 169–177. <https://doi.org/10.31887/DCNS.2020.22.2/lvalmaggia>
- Bell, S. (2012). *Landscape: Pattern, Perception and Process* (2nd ed.). Routledge. <https://doi.org/10.4324/9780203120088>
- Bell, S. (2019). Experiencing nature with sight impairment: Seeking freedom from ableism. *Environment and Planning E: Nature and Space*, 2(2), 304–322. <https://doi.org/10.1177/2514848619835720>
- Bell, S. L., & Bush, T. N. (2021). ‘Never mind the bullocks’: Animating the go-along interview through creative nonfiction. *Mobilities*, 16(3), 306–321. <https://doi.org/10.1080/17450101.2020.1817685>
- Bell, S. L., & Foley, R. (2021). A(nother) time for nature? Situating non-human nature experiences within the emotional transitions of sight loss. *Social Science & Medicine*, 276, 113867. <https://doi.org/10.1016/j.socscimed.2021.113867>
- Bell, S., Leyshon, C., & Phoenix, C. (2019). Negotiating nature’s weather worlds in the context of life with sight impairment. *Transactions of the Institute of British Geographers*, 44(2), 270–283. <https://doi.org/10.1111/tran.12285>
- Benton, J. S., Cotterill, S., Anderson, J., Macintyre, V. G., Gittins, M., Dennis, M., Lindley, S. J., & French, D. P. (2021). Impact of a low-cost urban green space intervention on wellbeing behaviours in older adults: A natural experimental study. *Wellbeing, Space and Society*, 2, 100029. <https://doi.org/10.1016/j.wss.2021.100029>
- Berto, R. (2005). Exposure to restorative environments helps restore attentional capacity. *Journal of Environmental Psychology*, 25(3), 249–259. <https://doi.org/10.1016/j.jenvp.2005.07.001>
- Bertram, C., & Rehdanz, K. (2015). The role of urban green space for human well-being. *Ecological Economics*, 120, 139–152. <https://doi.org/10.1016/j.ecolecon.2015.10.013>
- Beukeboom, C. J., Langeveld, D., & Tanja-Dijkstra, K. (2012). Stress-reducing effects of real and artificial nature in a hospital waiting room. *Journal of Alternative and Complementary Medicine (New York, N.Y.)*, 18(4), 329–333. <https://doi.org/10.1089/acm.2011.0488>

- Beute, F., & De Kort, Y. A. W. (2019). Thinking of nature: Associations with natural versus urban environments and their relation to preference. *Landscape Research*, 44(4), 374–392. <https://doi.org/10.1080/01426397.2018.1457144>
- Bhaskar, R. (2020). Critical realism and the ontology of persons*. *Journal of Critical Realism*, 19(2), 113–120. <https://doi.org/10.1080/14767430.2020.1734736>
- Bhugra, D., Castaldelli-Maia, J. M., Torales, J., & Ventriglio, A. (2019). Megacities, migration, and mental health. *Lancet Psychiatry*, ePub(ePub), ePub. [https://doi.org/10.1016/S2215-0366\(19\)30294-9](https://doi.org/10.1016/S2215-0366(19)30294-9)
- Biggs, S., & Carr, A. (2016). Age Friendliness, Childhood, and Dementia: Toward Generationally Intelligent Environments (pp. 259–276). https://doi.org/10.1007/978-3-319-24031-2_15
- Birch, J., Rishbeth, C., & Payne, S. R. (2020). Nature doesn't judge you – how urban nature supports young people's mental health and wellbeing in a diverse UK city. *Health & Place*, 62, 102296. <https://doi.org/10.1016/j.healthplace.2020.102296>
- Bixler, R. D., & Floyd, M. F. (1997). Nature is Scary, Disgusting, and Uncomfortable. *Environment and Behavior*, 29(4), 443–467. <https://doi.org/10.1177/001391659702900401>
- Bjerke, T., Østdahl, T., Thrane, C., & Strumse, E. (2006). Vegetation density of urban parks and perceived appropriateness for recreation. *Urban Forestry & Urban Greening*, 5(1), 35–44. <https://doi.org/10.1016/j.ufug.2006.01.006>
- Blascovich, J., Loomis, J., Beall, A. C., Swin, K. R., Hoyt, C. L., & Bailenson, J. N. (2002). Immersive Virtual Environment Technology as a Methodological Tool for Social Psychology. *Psychological Inquiry*, 13(2), 103–124. https://doi.org/10.1207/S15327965PLI1302_01
- Bluhm, G. L., Berglind, N., Nordling, E., & Rosenlund, M. (2007). Road traffic noise and hypertension. *Occupational and Environmental Medicine*, 64(2), 122–126. <https://doi.org/10.1136/oem.2005.025866>
- Blum, J., Rockstroh, C., & Göritz, A. S. (2019). Heart Rate Variability Biofeedback Based on Slow-Paced Breathing With Immersive Virtual Reality Nature Scenery. *Frontiers in Psychology*, 10, 2172. <https://doi.org/10.3389/fpsyg.2019.02172>
- Bolouki, A. (2024). The impact of virtual reality natural and built environments on affective responses: A systematic review and meta-analysis. *International Journal of Environmental*

- Health Research, 34(1), 73–89. <https://doi.org/10.1080/09603123.2022.2130881>
- Bonnet, M. H., & Arand, D. L. (2001). Impact of activity and arousal upon spectral EEG parameters. *Physiology & Behavior*, 74(3), 291–298. [https://doi.org/10.1016/S0031-9384\(01\)00581-9](https://doi.org/10.1016/S0031-9384(01)00581-9)
- Bonsang, E., & van Soest, A. (2012). Satisfaction with Social Contacts of Older Europeans. *Social Indicators Research*, 105(2), 273–292. <https://doi.org/10.1007/s11205-011-9886-6>
- Bornioli, A., Parkhurst, G., & Morgan, P. L. (2018a). Psychological Wellbeing Benefits of Simulated Exposure to Five Urban Settings: An Experimental Study From the Pedestrian's Perspective. *Journal of Transport & Health*, 9, 105–116. <https://doi.org/10.1016/j.jth.2018.02.003>
- Bornioli, A., Parkhurst, G., & Morgan, P. L. (2018b). The psychological wellbeing benefits of place engagement during walking in urban environments: A qualitative photo-elicitation study. *Health & Place*, 53, 228–236. <https://doi.org/10.1016/j.healthplace.2018.08.018>
- Bornioli, A., & Subiza-Pérez, M. (2022). Restorative urban environments for healthy cities: A theoretical model for the study of restorative experiences in urban built settings. *Landscape Research*, 48, 1–12. <https://doi.org/10.1080/01426397.2022.2124962>
- Boyd, F., White, M. P., Bell, S. L., & Burt, J. (2018). Who doesn't visit natural environments for recreation and why: A population representative analysis of spatial, individual and temporal factors among adults in England. *Landscape and Urban Planning*, 175, 102–113. <https://doi.org/10.1016/j.landurbplan.2018.03.016>
- Brancato, G., Van Hedger, K., Berman, M. G., & Van Hedger, S. C. (2022). Simulated nature walks improve psychological well-being along a natural to urban continuum. *Journal of Environmental Psychology*, 81, 101779. <https://doi.org/10.1016/j.jenvp.2022.101779>
- Bratman, G. N., Anderson, C. B., Berman, M. G., Cochran, B., de Vries, S., Flanders, J., Folke, C., Frumkin, H., Gross, J. J., Hartig, T., Kahn, P. H., Kuo, M., Lawler, J. J., Levin, P. S., Lindahl, T., Meyer-Lindenberg, A., Mitchell, R., Ouyang, Z., Roe, J., ... Daily, G. C. (2019). Nature and mental health: An ecosystem service perspective. *Science Advances*, 5(7), eaax0903. <https://doi.org/10.1126/sciadv.aax0903>
- Braun, T., & Dierkes, P. (2017). Connecting students to nature – how intensity of nature experience and student age influence the success of outdoor education programs.

Environmental Education Research, 23(7), 937–949.

<https://doi.org/10.1080/13504622.2016.1214866> Braun, V., & Clarke, V. (2006). Using thematic analysis in psychology. *Qualitative Research in*

Psychology, 3(2), 77–101. <https://doi.org/10.1191/1478088706qp063oa>

Braun, V., & Clarke, V. (2013). *Successful Qualitative Research: A Practical Guide for Beginners*. SAGE Publications, Inc.

Bray, I., Reece, R., Sinnett, D., Martin, F., & Hayward, R. (2022). Exploring the role of exposure to green and blue spaces in preventing anxiety and depression among young people aged 14–24 years living in urban settings: A systematic review and conceptual framework. *Environmental Research*, 214, 114081.

<https://doi.org/10.1016/j.envres.2022.114081>

Bremner, J. D., Vythilingam, M., Vermetten, E., Adil, J., Khan, S., Nazeer, A., Afzal, N., McGlashan, T., Elzinga, B., Anderson, G. M., Heninger, G., Southwick, S. M., & Charney, D. S. (2003). Cortisol response to a cognitive stress challenge in posttraumatic stress disorder (PTSD) related to childhood abuse. *Psychoneuroendocrinology*, 28(6), 733–750.

[https://doi.org/10.1016/S0306-4530\(02\)00067-7](https://doi.org/10.1016/S0306-4530(02)00067-7)

Brewer, J., & Hunter, A. (1989). *Multimethod research: A synthesis of styles* (p. 209). Sage Publications, Inc.

Brielmann, A. A., Buras, N. H., Salingaros, N. A., & Taylor, R. P. (2022). What Happens in Your Brain When You Walk Down the Street? Implications of Architectural Proportions, Biophilia, and Fractal Geometry for Urban Science. *Urban Science*, 6(1), Article 1.

<https://doi.org/10.3390/urbansci6010003>

Brivio, E., Serino, S., Negro Cousa, E., Zini, A., Riva, G., & De Leo, G. (2021). Virtual reality and 360° panorama technology: A media comparison to study changes in sense of presence, anxiety, and positive emotions. *Virtual Reality*, 25(2), 303–311.

<https://doi.org/10.1007/s10055-020-00453-7>

Brown, C., de Lannoy, A., McCracken, D., Gill, T., Grant, M., Wright, H., & Williams, S. (2019). Special issue: Child-friendly cities. *Cities & Health*, 3(1–2), 1–7.

<https://doi.org/10.1080/23748834.2019.1682836>

Brown, K. M. (2017). The haptic pleasures of ground-feel: The role of textured terrain in motivating regular exercise. *Health & Place*, 46, 307–314.

<https://doi.org/10.1016/j.healthplace.2016.08.012>

Browning, M. H. E. M., Saeidi-Rizi, F., McAnirlin, O., Yoon, H., & Pei, Y. (2021). The Role of Methodological Choices in the Effects of Experimental Exposure to Simulated Natural Landscapes on Human Health and Cognitive Performance: A Systematic Review. *Environment and Behavior*, 53(7), 687–731. <https://doi.org/10.1177/0013916520906481>

Browning, M. H. E. M., Shipley, N., McAnirlin, O., Becker, D., Yu, C.-P., Hartig, T., & Dzhambov, A. M. (2020). An Actual Natural Setting Improves Mood Better Than Its Virtual Counterpart: A Meta-Analysis of Experimental Data. *Frontiers in Psychology*, 11. <https://doi.org/10.3389/fpsyg.2020.02200>

Bryant, L., Brunner, M., & Hemsley, B. (2020). A review of virtual reality technologies in the field of communication disability: Implications for practice and research. *Disability and Rehabilitation: Assistive Technology*, 15(4), 365–372. <https://doi.org/10.1080/17483107.2018.1549276>

Buras, N. H. (2020). *The Art of Classic Planning: Building Beautiful and Enduring Communities*. Belknap Press.

Burgess, J., Harrison, C. M., & Limb, M. (1988). People, Parks and the Urban Green: A Study of Popular Meanings and Values for Open Spaces in the City. *Urban Studies*, 25(6), 455–473. <https://doi.org/10.1080/00420988820080631>

Burle, B., Spieser, L., Roger, C., Casini, L., Hasbroucq, T., & Vidal, F. (2015). Spatial and temporal resolutions of EEG: Is it really black and white? A scalp current density view. *International Journal of Psychophysiology*, 97(3), 210–220. <https://doi.org/10.1016/j.ijpsycho.2015.05.004>

Burnett, H., Olsen, J. R., & Mitchell, R. (2022). Green Space Visits and Barriers to Visiting during the COVID-19 Pandemic: A Three-Wave Nationally Representative Cross-Sectional Study of UK Adults. *Land*, 11(4), Article 4. <https://doi.org/10.3390/land11040503>

Cahn, B. R., Delorme, A., & Polich, J. (2010). Occipital gamma activation during Vipassana meditation. *Cognitive Processing*, 11(1), 39–56. <https://doi.org/10.1007/s10339-009-0352-1>

Callaghan, A., McCombe, G., Harrold, A., McMeel, C., Mills, G., Moore-Cherry, N., & Cullen, W. (2020). The impact of green spaces on mental health in urban settings: A scoping review. *Journal of Mental Health (Abingdon, England)*, 30(2), 179–193. <https://doi.org/10.1080/09638237.2020.1755027>

- Calogiuri, G., Keegan, B. J., Birkheim, S. L., Rydgren, T. L., Flaten, O. E., Fröhlich, F., & Litleskare, S. (2022). A mixed-methods exploration of virtual reality as a tool to promote green exercise. *Scientific Reports*, 12(1), 5715. <https://doi.org/10.1038/s41598-022-09622-x>
- Campbell, H., & Musa, A. (2018). The Power of Play: Child-led Placemaking in Parks (pp. 68–72). <https://thecityateyelevel.com/app/uploads/2019/12/the-power-of-play.pdf>
- Cao, X., Wang, L., Yang, X., & Liu, Y. (2024). How Do Urban Nature Parks Contribute to Psychological Restoration? The Perspective of Embodied Experience. *Leisure Sciences*, 0(0), 1–21. <https://doi.org/10.1080/01490400.2024.2370529>
- Caperon, L., McEachan, R. R. C., Endacott, C., & Ahern, S. M. (2022). Evaluating Community Co-Design, Maintenance and Ownership of Green Spaces in Underserved Communities Using Participatory Research. *Journal of Participatory Research Methods*, 3(1). <https://doi.org/10.35844/001c.35632>
- Carrus, G., Laforteza, R., Colangelo, G., Dentamaro, I., Scopelliti, M., & Sanesi, G. (2013). Relations between naturalness and perceived restorativeness of different urban green spaces. *PsyEcology*, 4(3), 227–244. <https://doi.org/10.1174/217119713807749869>
- Carver, A., Rachele, J. N., Sugiyama, T., Corti, B.-G., Burton, N. W., & Turrell, G. (2024). Public greenspace and mental wellbeing among mid-older aged adults: Findings from the HABITAT longitudinal study. *Health & Place*, 89, 103311. <https://doi.org/10.1016/j.healthplace.2024.103311>
- Catissi, G., Gouveia, G., Savieto, R. M., Silva, C. P. R., de Almeida, R. S., Borba, G. B., Rosario, K. A., & Leão, E. R. (2024). Nature-Based Interventions Targeting Elderly People's Health and Well-Being: An Evidence Map. *International Journal of Environmental Research and Public Health*, 21(1), 112. <https://doi.org/10.3390/ijerph21010112>
- Cattell, V., Dines, N., Gesler, W., & Curtis, S. (2008). Mingling, observing, and lingering: Everyday public spaces and their implications for well-being and social relations. *Health & Place*, 14(3), 544–561. <https://doi.org/10.1016/j.healthplace.2007.10.007>
- Chan, S. H. M., Qiu, L., Esposito, G., & Mai, K. P. (2021). Vertical greenery buffers against stress: Evidence from psychophysiological responses in virtual reality. *Landscape and Urban Planning*, 213, 104127. <https://doi.org/10.1016/j.landurbplan.2021.104127>
- Chang, C., Cox, D. T. C., Fan, Q., Nghiem, T. P. L., Tan, C. L. Y., Oh, R. R. Y., Lin, B. B., Shanahan,

- D. F., Fuller, R. A., Gaston, K. J., & Carrasco, L. R. (2022). People's desire to be in nature and how they experience it are partially heritable. *PLOS Biology*, 20(2), e3001500.
<https://doi.org/10.1371/journal.pbio.3001500>
- Chang, C.-R., & Li, M.-H. (2014). Effects of urban parks on the local urban thermal environment. *Urban Forestry & Urban Greening*, 13(4), 672–681.
<https://doi.org/10.1016/j.ufug.2014.08.001>
- Chang, C.-Y., Hammitt, W. E., Chen, P.-K., Machnik, L., & Su, W.-C. (2008). Psychophysiological responses and restorative values of natural environments in Taiwan. *Landscape and Urban Planning*, 85(2), 79–84. <https://doi.org/10.1016/j.landurbplan.2007.09.010>
- Charness, G., Gneezy, U., & Kuhn, M. A. (2012). Experimental methods: Between-subject and within-subject design. *Journal of Economic Behavior & Organization*, 81(1), 1–8.
<https://doi.org/10.1016/j.jebo.2011.08.009>
- Chawla, L., Keena, K., Pevec, I., & Stanley, E. (2014). Green schoolyards as havens from stress and resources for resilience in childhood and adolescence. *Health & Place*, 28, 1–13.
<https://doi.org/10.1016/j.healthplace.2014.03.001>
- Chen, S., Wu, Z., Sleipness, O. R., & Wang, H. (2022). Benefits and Conflicts: A Systematic Review of Dog Park Design and Management Strategies. *Animals : An Open Access Journal from MDPI*, 12(17), 2251. <https://doi.org/10.3390/ani12172251>
- Chen, Z., He, Y., & Yu, Y. (2020). Attention restoration during environmental exposure via alpha-theta oscillations and synchronization. *Journal of Environmental Psychology*, 68, 101406. <https://doi.org/10.1016/j.jenvp.2020.101406>
- Cheron, G., Petit, G., Cheron, J., Leroy, A., Cebolla, A., Cevallos, C., Petieau, M., Hoellinger, T., Zarka, D., Clarinval, A.-M., & Dan, B. (2016). Brain Oscillations in Sport: Toward EEG Biomarkers of Performance. *Frontiers in Psychology*, 7.
<https://www.frontiersin.org/articles/10.3389/fpsyg.2016.00246>
- Chu, B., Marwaha, K., Sanvictores, T., Awosika, A. O., & Ayers, D. (2024). Physiology, Stress Reaction. In *StatPearls*. StatPearls Publishing.
<http://www.ncbi.nlm.nih.gov/books/NBK541120/>
- Clarke, M., Cadaval, S., Wallace, C., Anderson, E., Egerer, M., Dinkins, L., & Platero, R. (2023). Factors that enhance or hinder social cohesion in urban greenspaces: A literature review.

Urban Forestry & Urban Greening, 84, 127936. <https://doi.org/10.1016/j.ufug.2023.127936>

Cleary, A., Roiko, A., Burton, N. W., Fielding, K. S., Murray, Z., & Turrell, G. (2019). Changes in perceptions of urban green space are related to changes in psychological well-being: Crosssectional and longitudinal study of mid-aged urban residents. *Health & Place*, 59, 102201. <https://doi.org/10.1016/j.healthplace.2019.102201>

Clements, R. (2004). An Investigation of the Status of Outdoor Play. *Contemporary Issues in Early Childhood*, 5(1), 68–80. <https://doi.org/10.2304/ciec.2004.5.1.10>

Coburn, A., Vartanian, O., & Chatterjee, A. (2017). Buildings, Beauty, and the Brain: A Neuroscience of Architectural Experience. *Journal of Cognitive Neuroscience*, 29(9), 1521–1531. https://doi.org/10.1162/jocn_a_01146

Collins, R. M., Smith, D., Ogotu, B. O., Brown, K. A., Eigenbrod, F., & Spake, R. (2023). The relative effects of access to public greenspace and private gardens on mental health. *Landscape and Urban Planning*, 240, 104902. <https://doi.org/10.1016/j.landurbplan.2023.104902>

Collins, R. M., Spake, R., Brown, K. A., Ogotu, B. O., Smith, D., & Eigenbrod, F. (2020). A systematic map of research exploring the effect of greenspace on mental health. *Landscape and Urban Planning*, 201, 103823. <https://doi.org/10.1016/j.landurbplan.2020.103823>

Cooke, P. J., Melchert, T. P., & Connor, K. (2016). Measuring Well-Being: A Review of Instruments. *The Counseling Psychologist*, 44(5), 730–757. <https://doi.org/10.1177/0011000016633507>

Corazon, S. S., Sidenius, U., Poulsen, D. V., Gramkow, M. C., & Stigsdotter, U. K. (2019). Psycho-Physiological Stress Recovery in Outdoor Nature-Based Interventions: A Systematic Review of the Past Eight Years of Research. *International Journal of Environmental Research and Public Health*, 16(10), Article 10. <https://doi.org/10.3390/ijerph16101711>

Cronin-de-Chavez, A., Islam, S., & McEachan, R. R. C. (2019). Not a level playing field: A qualitative study exploring structural, community and individual determinants of greenspace use amongst low-income multi-ethnic families. *Health & Place*, 56, 118–126. <https://doi.org/10.1016/j.healthplace.2019.01.018>

Cushing, D. F., & van Vliet, W. (2016). Intergenerational Communities as Healthy Places for Meaningful Engagement and Interaction. In S. Punch, R. Vanderbeck, & T. Skelton (Eds.), *Families, Intergenerationality, and Peer Group Relations* (pp. 1–27). Springer. https://doi.org/10.1007/978-981-4585-92-7_10-1

Cvejić, R., Eler, K., Pintar, M., Železnikar, Š., Haase, D., Kabisch, N., & Strohbach, M. (2015). A typology of urban green spaces—Eco-system services provisioning services and demands (D3.1). Univerza v Ljubljana / Humboldt Universität zu Berlin.

https://assets.centralparknyc.org/pdfs/institute/p2pupelp/1.004_Greensurge_A+Typology+of+Urban+Green+Spaces.pdf

Cyril, S., Oldroyd, J. C., & Renzaho, A. (2013). Urbanisation, urbanicity, and health: A systematic review of the reliability and validity of urbanicity scales. *BMC Public Health*, 13(1), 513. <https://doi.org/10.1186/1471-2458-13-513>

Dankiw, K. A., Tsiros, M. D., Baldock, K. L., & Kumar, S. (2020). The impacts of unstructured nature play on health in early childhood development: A systematic review. *PLOS ONE*, 15(2), e0229006. <https://doi.org/10.1371/journal.pone.0229006>

de Keijzer, C., Basagaña, X., Tonne, C., Valentín, A., Alonso, J., Antó, J. M., Nieuwenhuijsen, M. J., Kivimäki, M., Singh-Manoux, A., Sunyer, J., & Dadvand, P. (2019). Long-term exposure to greenspace and metabolic syndrome: A Whitehall II study. *Environmental Pollution*, 255, 113231. <https://doi.org/10.1016/j.envpol.2019.113231>

de Keijzer, C., Foraster, M., Basagaña, X., Tonne, C., Garcia, L. A., Valentín, A., Kivimäki, M., Nieuwenhuijsen, M. J., Alonso, J., Antó, J. M., Singh-Manoux, A., Sunyer, J., & Dadvand, P. (2020). Long-Term Greenspace Exposure and Progression of Arterial Stiffness: The Whitehall II Cohort Study. *Environmental Health Perspectives*, 128(6), 067014. <https://doi.org/10.1289/EHP6159>

de Keijzer, C., Gascon, M., Nieuwenhuijsen, M. J., & Dadvand, P. (2016). Long-Term Green Space Exposure and Cognition Across the Life Course: A Systematic Review. *Current Environmental Health Reports*, 3(4), 468–477. <https://doi.org/10.1007/s40572-016-0116-x>

de Keijzer, C., Tonne, C., Basagaña, X., Valentín, A., Singh-Manoux, A., Alonso, J., Antó, J. M., Nieuwenhuijsen, M. J., Sunyer, J., & Dadvand, P. (2018). Residential Surrounding Greenness and Cognitive Decline: A 10-Year Follow-up of the Whitehall II Cohort. *Environmental Health Perspectives*, 126(7), 077003. <https://doi.org/10.1289/EHP2875>

de Keijzer, C., Tonne, C., Sabia, S., Basagaña, X., Valentín, A., Singh-Manoux, A., Antó, J. M., Alonso, J., Nieuwenhuijsen, M. J., Sunyer, J., & Dadvand, P. (2019). Green and blue spaces and physical functioning in older adults: Longitudinal analyses of the Whitehall II study. *Environment International*, 122, 346–356. <https://doi.org/10.1016/j.envint.2018.11.046>

de Lusignan, S., Thiru, K., Meredith, K., Majeed, A., & Johnson, P. (2000). Measuring blood pressure at the wrist: More comfortable for patients and more convenient for doctors? *Public Health*, 114(3), 165–168. <https://doi.org/10.1038/sj.ph.1900614>

de Vries, S., Have, M., van Dorsselaer, S., van Wezep, M., Hermans, T., & de Graaf, R. (2016). Local availability of green and blue space and prevalence of common mental disorders in the Netherlands. *BJPsych Open*, 2(6), 366–372. <https://doi.org/10.1192/bjpo.bp.115.002469>

de Vries, S., Verheij, R. A., Groenewegen, P. P., & Spreeuwenberg, P. (2003). Natural Environments—Healthy Environments? An Exploratory Analysis of the Relationship between Greenspace and Health. *Environment and Planning A: Economy and Space*, 35(10), 1717–1731. <https://doi.org/10.1068/a35111>

Deng, L., Luo, H., Ma, J., Huang, Z., Sun, L.-X., Jiang, M.-Y., Zhu, C.-Y., & Li, X. (2020). Effects of integration between visual stimuli and auditory stimuli on restorative potential and aesthetic preference in urban green spaces. *Urban Forestry & Urban Greening*, 53, 126702. <https://doi.org/10.1016/j.ufug.2020.126702>

Department for Culture Media & Sport. (2015). Taking Part 2014/15, Focus On: Wellbeing. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/476510/Taking_Part_201415_Focus_on_Wellbeing.pdf

Department for Environment Food & Rural Affairs. (2019). Statistical Digest of Rural England Population. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1028819/Rural_population__Oct_2021.pdf

Department for Levelling Up, Housing and Communities. (2023). English Housing Survey. <https://www.gov.uk/government/collections/english-housing-survey>

Department of Health and Social Care. (2023). Green social prescribing: Perceptions among clinicians and the public. GOV.UK.

<https://www.gov.uk/government/publications/greensocial-prescribing-perceptions-among-clinicians-and-the-public>

Derkzen, M. L. (2012). Experiencing the Urban Green Space—An exploratory study of visiting behaviour, perceptions and preferences in the urban green spaces of São Paulo, Brazil [Master Thesis]. <https://studenttheses.uu.nl/handle/20.500.12932/10373>

Dias, A. F., Gaya, A. R., Brand, C., Pizarro, A. I., Fochesatto, C. F., Mendes, T. M., Mota, J., Maia Santos, M. P., & Gaya, A. C. A. (2019). Distance from home to the nearest park and the use of the parks for physical activity: The mediator role of road safety perception in adolescents. *Public Health*, 168, 9–16. <https://doi.org/10.1016/j.puhe.2018.11.021>

Dicicco-Bloom, B., & Crabtree, B. F. (2006). The qualitative research interview. *Medical Education*, 40(4), 314–321. <https://doi.org/10.1111/j.1365-2929.2006.02418.x>

Diemer, J., Alpers, G. W., Peperkorn, H. M., Shiban, Y., & Mühlberger, A. (2015). The impact of perception and presence on emotional reactions: A review of research in virtual reality. *Frontiers in Psychology*, 6. <https://www.frontiersin.org/article/10.3389/fpsyg.2015.00026>

Diener, A., & Mudu, P. (2021). How can vegetation protect us from air pollution? A critical review on green spaces' mitigation abilities for air-borne particles from a public health perspective - with implications for urban planning. *Science of The Total Environment*, 796, 148605. <https://doi.org/10.1016/j.scitotenv.2021.148605>

Diener, E. (2009). *The Science of Well-Being: The Collected Works of Ed Diener*. Springer Science & Business Media.

Dinnie, E., Brown, K. M., & Morris, S. (2013). Reprint of “Community, cooperation and conflict: Negotiating the social well-being benefits of urban greenspace experiences”. *Landscape and Urban Planning*, 118, 103–111. <https://doi.org/10.1016/j.landurbplan.2013.07.011>

Dirin, A., Alamäki, A., & Suomala, J. (2019). Gender Differences in Perceptions of Conventional Video, Virtual Reality and Augmented Reality. *International Journal of Interactive Mobile Technologies (IJIM)*, 13(06), Article 06. <https://doi.org/10.3991/ijim.v13i06.10487>

- Ditzen, B., Neumann, I. D., Bodenmann, G., von Dawans, B., Turner, R. A., Ehlert, U., & Heinrichs, M. (2007). Effects of different kinds of couple interaction on cortisol and heart rate responses to stress in women. *Psychoneuroendocrinology*, 32(5), 565–574.
<https://doi.org/10.1016/j.psyneuen.2007.03.011>
- DiZio, P., & Lackner, J. R. (2000). Motion Sickness Side Effects and Aftereffects of Immersive Virtual Environments Created with Helmet-Mounted Visual Displays.
<https://apps.dtic.mil/sti/citations/ADP010619>
- Dolcos, S., Moore, M., & Katsumi, Y. (2018). Neuroscience and Well-Being. In *Handbook of Wellbeing*. DEF Publishers.
- Doran, C. M., & Kinchin, I. (2019). A review of the economic impact of mental illness. *Australian Health Review*, 43(1), 43. <https://doi.org/10.1071/AH16115>
- Douglas, O., Lennon, M., & Scott, M. (2017). Green space benefits for health and well-being: A life-course approach for urban planning, design and management. *Cities*, 66, 53–62.
<https://doi.org/10.1016/j.cities.2017.03.011>
- Druckman, J. N., Greene, D. P., & Kuklinski, J. H. (2011). Students as Experimental Participants: A Defence of the ‘Narrow Data Base’. In *Cambridge Handbook of Experimental Political Science*. Cambridge University Press.
- Du, H., Zhou, F., Cai, Y., Li, C., & Xu, Y. (2021). Influence of Features of Green Spaces on Health and Well-Being: Case Study of Shanghai, China. *Journal of Urban Planning and Development*, 147(2), 04021008. [https://doi.org/10.1061/\(ASCE\)UP.1943-5444.0000671](https://doi.org/10.1061/(ASCE)UP.1943-5444.0000671)
- Duedahl, E., Blichfeldt, B., & Liburd, J. (2022). How engaging with nature can facilitate active healthy ageing. *Tourism Geographies*, 24(6–7), 1082–1102.
<https://doi.org/10.1080/14616688.2020.1819398>
- Dunn, P. N., & Coulton, D. C. (2016). Future of health and healthcare provision in cities. Government Office for Science.
<https://assets.publishing.service.gov.uk/media/5a7f8b7e40f0b62305b87cb6/gs-16-15future-of-cities-health-healthcare-provision.pdf>
- Elsadek, M., Liu, B., & Xie, J. (2020). Window view and relaxation: Viewing green space from a high-rise estate improves urban dwellers’ wellbeing. *Urban Forestry & Urban Greening*, 55, 126846. <https://doi.org/10.1016/j.ufug.2020.126846>

- Eriksson, N. T., & Wiklund-Gustin, L. (2014). Blessed Alienation: The Christian Monastery as a Caring and Restorative Environment. *Qualitative Health Research*, 24(2), 172–182.
<https://doi.org/10.1177/1049732313519708>
- Evans, G., Lepore, S., Shejwal, B. & Palsane, M. (1998). Chronic residential crowding and children's well-being: an ecological perspective. *Child Development*, 69(6), 1514.
- Evans, G. W., Otto, S., & Kaiser, F. G. (2018). Childhood Origins of Young Adult Environmental Behavior. *Psychological Science*, 29(5), 679–687.
<https://doi.org/10.1177/0956797617741894>
- Farinha-Marques, P., Lameiras, J. M., Fernandes, C., Silva, S., & Guilherme, F. (2011). Urban biodiversity: A review of current concepts and contributions to multidisciplinary approaches. *Innovation: The European Journal of Social Science Research*, 24(3), 247–271.
<https://doi.org/10.1080/13511610.2011.592062>
- Feng, Y., Duives, D. C., & Hoogendoorn, S. P. (2022). Development and evaluation of a VR research tool to study wayfinding behaviour in a multi-story building. *Safety Science*, 147, 105573. <https://doi.org/10.1016/j.ssci.2021.105573>
- Ferreira, S. O. (2019). Emotional activation in human beings: Procedures for experimental stress induction. *Psicologia USP*, 30, e180176.
- Fett, A.-K. J., Lemmers-Jansen, I. L. J., & Krabbendam, L. (2019). Psychosis and urbanicity: A review of the recent literature from epidemiology to neurourbanism. *Current Opinion in Psychiatry*, 32(3), 232. <https://doi.org/10.1097/YCO.0000000000000486>
- Finlay, J., Franke, T., McKay, H., & Sims-Gould, J. (2015). Therapeutic landscapes and wellbeing in later life: Impacts of blue and green spaces for older adults. *Health & Place*, 34, 97–106. <https://doi.org/10.1016/j.healthplace.2015.05.001>
- Finlay, J. M., & Bowman, J. A. (2017). Geographies on the Move: A Practical and Theoretical Approach to the Mobile Interview. *The Professional Geographer*, 69(2), 263–274.
<https://doi.org/10.1080/00330124.2016.1229623>
- Fitzgerald, K. G., & Caro, F. G. (2014). An Overview of Age-Friendly Cities and Communities Around the World. *Journal of Aging & Social Policy*, 26(1–2), 1–18.
<https://doi.org/10.1080/08959420.2014.860786>
- Fleming, C. M., Manning, M., & Ambrey, C. L. (2016). Crime, greenspace and life satisfaction:

An evaluation of the New Zealand experience. *Landscape and Urban Planning*, 149, 1–10.
<https://doi.org/10.1016/j.landurbplan.2015.12.014>

Fleuret, S., & Atkinson, S. (2007). Wellbeing, health and geography: A critical review and research agenda. *New Zealand Geographer*, 63(2), 106–118.
<https://doi.org/10.1111/j.1745-7939.2007.00093.x>

Fleury-Bahi, G., Galharret, J.-M., Lemée, C., Wittenberg, I., Olivos, P., Loureiro, A., Jeuken, Y., Laille, P., & Navarro, O. (2023). Nature and well-being in seven European cities: The moderating effect of connectedness to nature. *Applied Psychology: Health and Well-Being*, 15(2), 479–498. <https://doi.org/10.1111/aphw.12390>

Flouri, E., Midouhas, E., & Joshi, H. (2014). The role of urban neighbourhood green space in children's emotional and behavioural resilience. *Journal of Environmental Psychology*, 40, 179–186. <https://doi.org/10.1016/j.jenvp.2014.06.007>

Foley, R., & Kistemann, T. (2015). Blue space geographies: Enabling health in place. *Health & Place*, 35, 157–165. <https://doi.org/10.1016/j.healthplace.2015.07.003>

Fornara, F. (2011). Are “attractive” built places as restorative and emotionally positive as natural places in the urban environment? (pp. 159–170).

Fornara, F., & Troffa, R. (2009). Restorative experiences and perceived affective qualities in different built and natural urban places. (p. CD-ROM, p. 1).

Fouad, A. T. Z., Sinnett, D., Bray, I., McClatchey, R., & Reece, R. (2023). Measures of Greenspace Exposure and Their Association to Health-Related Outcomes for the Periods before and during the 2020 Lockdown: A Cross-Sectional Study in the West of England. *Land*, 12(4), Article 4. <https://doi.org/10.3390/land12040728>

Francis, J., Giles-Corti, B., Wood, L., & Knuiman, M. (2012). Creating sense of community: The role of public space. *Journal of Environmental Psychology*, 32(4), 401–409.
<https://doi.org/10.1016/j.jenvp.2012.07.002>

Francis, J., Wood, L. J., Knuiman, M., & Giles-Corti, B. (2012). Quality or quantity? Exploring the relationship between Public Open Space attributes and mental health in Perth, Western Australia. *Social Science & Medicine* (1982), 74(10), 1570–1577.
<https://doi.org/10.1016/j.socscimed.2012.01.032>

- Frost, S., Kannis-Dymand, L., Schaffer, V., Millea, P., Allen, A., Stallman, H., Mason, J., Wood, A., & Atkinson-Nolte, J. (2022). Virtual immersion in nature and psychological well-being: A systematic literature review. *Journal of Environmental Psychology*, 80, 101765.
<https://doi.org/10.1016/j.jenvp.2022.101765>
- Frumkin, H., Bratman, G. N., Breslow, S. J., Cochran, B., Kahn Jr, P. H., Lawler, J. J., Levin, P. S., Tandon, P. S., Varanasi, U., Wolf, K. L., & Wood, S. A. (2017). Nature Contact and Human Health: A Research Agenda. *Environmental Health Perspectives*, 125(7), 075001.
<https://doi.org/10.1289/EHP1663>
- Gaikwad, A., & Shinde, K. (2019). Use of parks by older persons and perceived health benefits: A developing country context. *Cities*, 84, 134–142.
<https://doi.org/10.1016/j.cities.2018.08.001>
- Gale, N. K., Heath, G., Cameron, E., Rashid, S., & Redwood, S. (2013). Using the framework method for the analysis of qualitative data in multi-disciplinary health research. *BMC Medical Research Methodology*, 13(1), 117. <https://doi.org/10.1186/1471-2288-13-117>
- Galindo, M. P., & Hidalgo, M. C. (2005). Aesthetic preferences and the attribution of meaning: Environmental categorization processes in the evaluation of urban scenes. *International Journal of Psychology*, 40(1), 19–27.
<https://doi.org/10.1080/00207590444000104>
- Gallagher, M. W., Lopez, S. J., & Preacher, K. J. (2009). The Hierarchical Structure of Well-Being. *Journal of Personality*, 77(4), 1025–1050. <https://doi.org/10.1111/j.1467-6494.2009.00573.x>
- Gamble, K. R., Howard, J. H., & Howard, D. V. (2014). Not Just Scenery: Viewing Nature Pictures Improves Executive Attention in Older Adults. *Experimental Aging Research*, 40(5), 513–530. <https://doi.org/10.1080/0361073X.2014.956618>
- Gao, T., Zhang, T., Zhu, L., Gao, Y., & Qiu, L. (2019). Exploring Psychophysiological Restoration and Individual Preference in the Different Environments Based on Virtual Reality. *International Journal of Environmental Research and Public Health*, 16(17), 3102.
<https://doi.org/10.3390/ijerph16173102>
- Gascon, M., Triguero-Mas, M., Martínez, D., Dadvand, P., Forns, J., Plasència, A., & Nieuwenhuijsen, M. J. (2015). Mental Health Benefits of Long-Term Exposure to Residential Green and Blue Spaces: A Systematic Review. *International Journal of Environmental*

- Research and Public Health, 12(4), Article 4. <https://doi.org/10.3390/ijerph120404354>
- Gascon, M., Triguero-Mas, M., Martínez, D., Dadvand, P., Rojas-Rueda, D., Plasència, A., & Nieuwenhuijsen, M. J. (2016). Residential green spaces and mortality: A systematic review. *Environment International*, 86, 60–67. <https://doi.org/10.1016/j.envint.2015.10.013>
- Gascon, M., Zijlema, W., Vert, C., White, M. P., & Nieuwenhuijsen, M. J. (2017). Outdoor blue spaces, human health and well-being: A systematic review of quantitative studies. *International Journal of Hygiene and Environmental Health*, 220(8), 1207–1221. <https://doi.org/10.1016/j.ijheh.2017.08.004>
- Gatersleben, B., & Andrews, M. (2013). When walking in nature is not restorative—The role of prospect and refuge. *Health & Place*, 20, 91–101. <https://doi.org/10.1016/j.healthplace.2013.01.001>
- Gaunet, F., Pari-Perrin, E., & Bernardin, G. (2014). Description of Dogs and Owners in Outdoor Built-Up Areas and Their More-Than-Human Issues. *Environmental Management*, 54(3), 383–401. <https://doi.org/10.1007/s00267-014-0297-8>
- Gautam, S., Jain, A., Chaudhary, J., Gautam, M., Gaur, M., & Grover, S. (2024). Concept of mental health and mental well-being, it's determinants and coping strategies. *Indian Journal of Psychiatry*, 66(Suppl 2), S231–S244. https://doi.org/10.4103/indianjpsychiatry.indianjpsychiatry_707_23
- GBD 2019 Mental Disorders Collaborators. (2022). Global, regional, and national burden of 12 mental disorders in 204 countries and territories, 1990–2019: A systematic analysis for the Global Burden of Disease Study 2019. *The Lancet Psychiatry*, 9(2), 137–150. [https://doi.org/10.1016/S2215-0366\(21\)00395-3](https://doi.org/10.1016/S2215-0366(21)00395-3)
- Gehring, U., Wijga, A. H., Brauer, M., Fischer, P., de Jongste, J. C., Kerkhof, M., Oldenwening, M., Smit, H. A., & Brunekreef, B. (2010). Traffic-related Air Pollution and the Development of Asthma and Allergies during the First 8 Years of Life. *American Journal of Respiratory and Critical Care Medicine*, 181(6), 596–603. <https://doi.org/10.1164/rccm.200906-0858OC>
- Gianfredi, V., Buffoli, M., Rebecchi, A., Croci, R., Oradini-Alacreu, A., Stirparo, G., Marino, A., Odone, A., Capolongo, S., & Signorelli, C. (2021). Association between Urban Greenspace and Health: A Systematic Review of Literature. *International Journal of Environmental Research and Public Health*, 18(10), Article 10. <https://doi.org/10.3390/ijerph18105137>

Gidlöf-Gunnarsson, A., & Öhrström, E. (2007). Noise and well-being in urban residential environments: The potential role of perceived availability to nearby green areas. *Landscape and Urban Planning*, 83(2), 115–126. <https://doi.org/10.1016/j.landurbplan.2007.03.003>

Gidlow, C. J., & Ellis, N. J. (2011). Neighbourhood green space in deprived urban communities: Issues and barriers to use. *Local Environment*, 16(10), 989–1002. <https://doi.org/10.1080/13549839.2011.582861>

Gidlow, C. J., Jones, M. V., Hurst, G., Masterson, D., Clark-Carter, D., Tarvainen, M. P., Smith, G., & Nieuwenhuijsen, M. (2016). Where to put your best foot forward: Psycho-physiological responses to walking in natural and urban environments. *Journal of Environmental Psychology*, 45, 22–29. <https://doi.org/10.1016/j.jenvp.2015.11.003>

Goldsmith, L. J. (2021, June 1). Using Framework Analysis in Applied Qualitative Research. | Qualitative Report | EBSCOhost. <https://doi.org/10.46743/2160-3715/2021.5011>

Gorini, A., & Riva, G. (2008). Virtual reality in anxiety disorders: The past and the future. *Expert Review of Neurotherapeutics*, 8(2), 215–233. <https://doi.org/10.1586/14737175.8.2.215>

Graham, H., & White, P. C. L. (2016). Social determinants and lifestyles: Integrating environmental and public health perspectives. *Public Health*, 141, 270–278. <https://doi.org/10.1016/j.puhe.2016.09.019>

Grahn, P., & Stigsdotter, U. K. (2010). The relation between perceived sensory dimensions of urban green space and stress restoration. *Landscape and Urban Planning*, 94(3–4), 264–275. <https://doi.org/10.1016/j.landurbplan.2009.10.012>

Grassini, S. (2022). A Systematic Review and Meta-Analysis of Nature Walk as an Intervention for Anxiety and Depression. *Journal of Clinical Medicine*, 11(6), 1731. <https://doi.org/10.3390/jcm11061731>

Grassini, S., Segurini, G. V., & Koivisto, M. (2022). Watching Nature Videos Promotes Physiological Restoration: Evidence From the Modulation of Alpha Waves in Electroencephalography. *Frontiers in Psychology*, 13, 871143. <https://doi.org/10.3389/fpsyg.2022.871143>

Groshong, L., Wilhelm Stanis, S. A., Kaczynski, A. T., & Hipp, J. A. (2020). Attitudes About

Perceived Park Safety Among Residents in Low-Income and High Minority Kansas City, Missouri, Neighborhoods. *Environment and Behavior*, 52(6), 639–665.

<https://doi.org/10.1177/0013916518814291>

Gruebner, O., A. Rapp, M., Adli, M., Kluge, U., Galea, S., & Heinz, A. (2017). Cities and Mental Health. *Deutsches Ärzteblatt International*, 114(8), 121–127.

<https://doi.org/10.3238/arztebl.2017.0121>

Güntürkün, O., Ströckens, F., & Ocklenburg, S. (2020). Brain Lateralization: A Comparative Perspective. *Physiological Reviews*, 100(3), 1019–1063.

<https://doi.org/10.1152/physrev.00006.2019>

Guo, S., Song, C., Pei, T., Liu, Y., Ma, T., Du, Y., Chen, J., Fan, Z., Tang, X., Peng, Y., & Wang, Y. (2019). Accessibility to urban parks for elderly residents: Perspectives from mobile phone data. *Landscape and Urban Planning*, 191, 103642.

<https://doi.org/10.1016/j.landurbplan.2019.103642>

Hall, D. A., Irwin, A., Edmondson-Jones, M., Phillips, S., & Poxon, J. E. W. (2013). An exploratory evaluation of perceptual, psychoacoustic and acoustical properties of urban soundscapes. *Applied Acoustics*, 74(2), 248–254.

<https://doi.org/10.1016/j.apacoust.2011.03.006>

Han, I., Shin, H. S., Ko, Y., & Shin, W. S. (2022). Immersive virtual reality for increasing presence and empathy. *Journal of Computer Assisted Learning*, n/a(n/a).

<https://doi.org/10.1111/jcal.12669>

Hanel, P. H. P., & Vione, K. C. (2016). Do Student Samples Provide an Accurate Estimate of the General Public? *PLoS ONE*, 11(12), e0168354.

<https://doi.org/10.1371/journal.pone.0168354>

Hanson, H. I., Eckberg, E., Widenberg, M., & Alkan Olsson, J. (2021). Gardens' contribution to people and urban green space. *Urban Forestry & Urban Greening*, 63, 127198.

<https://doi.org/10.1016/j.ufug.2021.127198>

Hartig, T. (2021). Restoration in Nature: Beyond the Conventional Narrative. In A. R. Schutte, J. C. Torquati, & J. R. Stevens (Eds.), *Nature and Psychology: Biological, Cognitive, Developmental, and Social Pathways to Well-being* (pp. 89–151). Springer International Publishing. https://doi.org/10.1007/978-3-030-69020-5_5

- Hartig, T., Evans, G. W., Jamner, L. D., Davis, D. S., & Gärling, T. (2003). Tracking restoration in natural and urban field settings. *Journal of Environmental Psychology*, 23(2), 109–123.
[https://doi.org/10.1016/S0272-4944\(02\)00109-3](https://doi.org/10.1016/S0272-4944(02)00109-3)
- Hartig, T., Korpela, K., Evans, G. W., & Gärling, T. (1997). A measure of restorative quality in environments. *Scandinavian Housing and Planning Research*, 14(4), 175–194.
<https://doi.org/10.1080/02815739708730435>
- Hartig, T., Mitchell, R., de Vries, S., & Frumkin, H. (2014). Nature and health. *Annual Review of Public Health*, 35, 207–228. <https://doi.org/10.1146/annurev-publhealth-032013-182443>
- Hassan, A., Qibing, C., & Tao, J. (2018). Physiological and psychological effects of gardening activity in older adults. *Geriatrics & Gerontology International*, 18(8), 1147–1152.
<https://doi.org/10.1111/ggi.13327>
- Haywood, A., Dayson, C., Garside, R., Foster, A., Lovell, R., Husk, K., Holding, E., Thompson, J., Shearn, K., Hunt, H. A., Dobson, J., Harris, C., Jacques, R., Witherley, D., Northall, P., Baumann, M., & Wilson, I. (2024). National Evaluation of the Preventing and Tackling Mental Ill Health through Green Social Prescribing Project (BE0191). Department for Environment, Food and Rural Affairs.
https://beyondgreenspace.net/wpcontent/uploads/2024/09/21194_gspevaluationfinalreport-mainreportjan2024-4-1.pdf
- Hedblom, M., Gunnarsson, B., Iravani, B., Knez, I., Schaefer, M., Thorsson, P., & Lundström, J. N. (2019). Reduction of physiological stress by urban green space in a multisensory virtual experiment. *Scientific Reports*, 9(1), 10113. <https://doi.org/10.1038/s41598-019-46099-7>
- Hedblom, M., Knez, I., Ode Sang, Å., & Gunnarsson, B. (2017). Evaluation of natural sounds in urban greenery: Potential impact for urban nature preservation. *Royal Society Open Science*, 4(2), 170037. <https://doi.org/10.1098/rsos.170037>
- Henderson, L., & Knight, T. (2012). Integrating the hedonic and eudaimonic perspectives to more comprehensively understand wellbeing and pathways to wellbeing.
<https://doi.org/10.5502/ijw.v2i3.3>
- Hennink, M., & Kaiser, B. N. (2022). Sample sizes for saturation in qualitative research: A systematic review of empirical tests. *Social Science & Medicine*, 292, 114523.
<https://doi.org/10.1016/j.socscimed.2021.114523>

Heo, S., Desai, M. U., Lowe, S. R., & Bell, M. L. (2021). Impact of Changed Use of Greenspace during COVID-19 Pandemic on Depression and Anxiety. *International Journal of Environmental Research and Public Health*, 18(11), Article 11.

<https://doi.org/10.3390/ijerph18115842>

Herranz-Pascual, K., Aspuru, I., Iraurgi, I., Santander, Á., Eguiguren, J. L., & García, I. (2019). Going beyond Quietness: Determining the Emotionally Restorative Effect of Acoustic Environments in Urban Open Public Spaces. *International Journal of Environmental Research and Public Health*, 16(7), Article 7. <https://doi.org/10.3390/ijerph16071284>

Herrman, H. (2001). The Need for Mental Health Promotion. *Australian & New Zealand Journal of Psychiatry*, 35(6), 709–715. <https://doi.org/10.1046/j.1440-1614.2001.00947.x>

Herzog, T. R., Chen, H. C., & Primeau, J. S. (2002). Perception of the restorative potential of natural and other settings. *Journal of Environmental Psychology*, 22(3), 295–306.

<https://doi.org/10.1006/jevp.2002.0235>

Herzog, T. R., Colleen, Maguire, P., & Nebel, M. B. (2003). Assessing the restorative components of environments. *Journal of Environmental Psychology*, 23(2), 159–170.

[https://doi.org/10.1016/S0272-4944\(02\)00113-5](https://doi.org/10.1016/S0272-4944(02)00113-5)

Herzog, T. R., Ouellette, P., Rolens, J. R., & Koenigs, A. M. (2010). Houses of Worship as Restorative Environments. *Environment and Behavior*, 42(4), 395–419.

<https://doi.org/10.1177/0013916508328610>

Hewlett, E., & Moran, V. (2014). Making Mental Health Count: The Social and Economic Costs of Neglecting Mental Health Care | Policy Commons.

<https://policycommons.net/artifacts/12929309/making-mental-health-count/13827104/>

Hidalgo, M., Berto, R., Galindo, M., & Getrevi, A. (2005). Identifying attractive and unattractive urban places: Categories, restorativeness and aesthetic attributes. *Medio Ambiente y Comportamiento Humano*, 7, 115–133.

Historic England. (2014). 2014 – The Value and Impact of Heritage | Historic England.

<https://historicengland.org.uk/research/heritage-counts/2014-the-value-and-impact-ofheritage/>

- Home, R., Hunziker, M., & Bauer, N. (2012). Psychosocial Outcomes as Motivations for Visiting Nearby Urban Green Spaces. *Leisure Sciences*, 34(4), 350–365.
<https://doi.org/10.1080/01490400.2012.687644>
- Honey-Rosés, J., & Zapata, O. (2023). Green Spaces with Fewer People Improve SelfReported Affective Experience and Mood. *International Journal of Environmental Research and Public Health*, 20(2), Article 2. <https://doi.org/10.3390/ijerph20021219>
- Hong, A., Sallis, J. F., King, A. C., Conway, T. L., Saelens, B., Cain, K. L., Fox, E. H., & Frank, L. D. (2018). Linking green space to neighborhood social capital in older adults: The role of perceived safety. *Social Science & Medicine* (1982), 207, 38–45.
<https://doi.org/10.1016/j.socscimed.2018.04.051>
- Hong, S.-K., Lee, S.-W., Jo, H.-K., & Yoo, M. (2019). Impact of Frequency of Visits and Time Spent in Urban Green Space on Subjective Well-Being. *Sustainability*, 11(15), Article 15.
<https://doi.org/10.3390/su11154189>
- Hooyberg, A., Michels, N., Roose, H., Everaert, G., Mokas, I., Malina, R., Vanderhasselt, M.A., & De Henauw, S. (2023). The psychophysiological reactivity to beaches vs. to green and urban environments: Insights from a virtual reality experiment. *Journal of Environmental Psychology*, 102103. <https://doi.org/10.1016/j.jenvp.2023.102103>
- Hou, H.-R., Zhang, X.-N., & Meng, Q.-H. (2020). Odor-induced emotion recognition based on average frequency band division of EEG signals. *Journal of Neuroscience Methods*, 334, 108599. <https://doi.org/10.1016/j.jneumeth.2020.108599>
- Houlden, V., Weich, S., Porto de Albuquerque, J., Jarvis, S., & Rees, K. (2018). The relationship between greenspace and the mental wellbeing of adults: A systematic review. *PLOS ONE*, 13(9), e0203000. <https://doi.org/10.1371/journal.pone.0203000>
- Howarth, M., Brettle, A., Hardman, M., & Maden, M. (2020). What is the evidence for the impact of gardens and gardening on health and well-being: A scoping review and evidence-based logic model to guide healthcare strategy decision making on the use of gardening approaches as a social prescription. *BMJ Open*, 10(7), e036923.
<https://doi.org/10.1136/bmjopen-2020-036923>
- Huang, Q., Yang, M., Jane, H., Li, S., & Bauer, N. (2020). Trees, grass, or concrete? The effects of different types of environments on stress reduction. *Landscape and Urban Planning*, 193, 103654. <https://doi.org/10.1016/j.landurbplan.2019.103654>

- Huang, R. S., Kuo, C. J., Tsai, L.-L., & Chen, O. T. C. (1996). EEG pattern recognition-arousal states detection and classification. *Proceedings of International Conference on Neural Networks (ICNN'96)*, 2, 641–646 vol.2. <https://doi.org/10.1109/ICNN.1996.548971>
- Huang, S., Qi, J., Li, W., Dong, J., & van den Bosch, C. K. (2021). The Contribution to Stress Recovery and Attention Restoration Potential of Exposure to Urban Green Spaces in Low-Density Residential Areas. *International Journal of Environmental Research and Public Health*, 18(16), 8713. <https://doi.org/10.3390/ijerph18168713>
- Huang, S.-C. L., Chiang, N. C., Kuo, N.-F., & Chen, Y.-J. (2019). An exploratory approach for using EEG to examine person-environment interaction. *Landscape Research*, 44(6), 702–715. <https://doi.org/10.1080/01426397.2018.1548586>
- Huang, Y., Lei, C., Liu, C.-H., Perez, P., Forehead, H., Kong, S., & Zhou, J. L. (2021). A review of strategies for mitigating roadside air pollution in urban street canyons. *Environmental Pollution*, 280, 116971. <https://doi.org/10.1016/j.envpol.2021.116971>
- Hunter, A., & Brewer, J. D. (2015). Designing Multimethod Research. In S. N. Hesse-Biber & R. B. Johnson (Eds.), *The Oxford Handbook of Multimethod and Mixed Methods Research Inquiry* (p. 0). Oxford University Press. <https://doi.org/10.1093/oxfordhb/9780199933624.013.13>
- Hunter, R. F., Christian, H., Veitch, J., Astell-Burt, T., Hipp, J. A., & Schipperijn, J. (2015). The impact of interventions to promote physical activity in urban green space: A systematic review and recommendations for future research. *Social Science & Medicine*, 124, 246–256. <https://doi.org/10.1016/j.socscimed.2014.11.051>
- Hunter, R. F., Cleland, C., Cleary, A., Droomers, M., Wheeler, B. W., Sinnett, D., Nieuwenhuijsen, M. J., & Braubach, M. (2019). Environmental, health, wellbeing, social and equity effects of urban green space interventions: A meta-narrative evidence synthesis. *Environment International*, 130, 104923. <https://doi.org/10.1016/j.envint.2019.104923>
- Hystad, P., Payette, Y., Noisel, N., & Boileau, C. (2019). Green space associations with mental health and cognitive function: Results from the Quebec CARTaGENE cohort. *Environmental Epidemiology*, 3(1), e040. <https://doi.org/10.1097/EE9.0000000000000040>
- Ivankova, N. V., & Plano Clark, V. L. (2018). Teaching mixed methods research: Using a socioecological framework as a pedagogical approach for addressing the complexity of the field*.

International Journal of Social Research Methodology, 21(4), 409–424.

<https://doi.org/10.1080/13645579.2018.1427604>

Jabbar, M., Yusoff, M. M., & Shafie, A. (2021). Assessing the role of urban green spaces for human well-being: A systematic review. *GeoJournal*, 87(5), 4405–4423.

<https://doi.org/10.1007/s10708-021-10474-7>

James, K., & Embrey, L. (2001). “Anyone could be lurking around!”: Constraints on adolescent girls’ recreational activities after dark. *World Leisure Journal*, 43(4), 44–52.

<https://doi.org/10.1080/04419057.2001.9674248>

Jané-Llopis, E., Barry, M., Hosman, C., & Patel, V. (2005). Mental health promotion works: A review. *Promotion & Education*, 12(2_suppl), 9–25.

<https://doi.org/10.1177/10253823050120020103x>

Jansen, I., & Petrova, S. (2023). Driving Towards Sustainability: Electric Vehicles’ Contribution to Environmental and Public Health. *Journal of Sustainable Technologies and Infrastructure Planning*, 7(1), Article 1.

Jarden, A., & Roache, A. (2023). What Is Wellbeing? *International Journal of Environmental Research and Public Health*, 20(6), 5006. <https://doi.org/10.3390/ijerph20065006>

Jennings, V., & Bamkole, O. (2019). The Relationship between Social Cohesion and Urban Green Space: An Avenue for Health Promotion. *International Journal of Environmental Research and Public Health*, 16(3), Article 3. <https://doi.org/10.3390/ijerph16030452>

Jiménez, T. R., & Orozco, M. (2021). Prompts, Not Questions: Four Techniques for Crafting Better Interview Protocols. *Qualitative Sociology*, 44(4), 507–528.

<https://doi.org/10.1007/s11133-021-09483-2>

Johnson, R. B., Onwuegbuzie, A. J., & Turner, L. A. (2007). Toward a Definition of Mixed Methods Research. *Journal of Mixed Methods Research*, 1(2), 112–133.

<https://doi.org/10.1177/1558689806298224>

Jöhr, J., Martinez, T., Marquis, R., Bruce, S., Binz, P.-A., Rey, S., Hafner, G., Attwell, C., & Diserens, K. (2023). Measuring Salivary Cortisol to Assess the Effect of Natural Environments on Stress Level in Acute Patients With Severe Brain Injuries: An Exploratory Study. *Cureus*, 15(9), e44878. <https://doi.org/10.7759/cureus.44878>

- Jones, M. V., Gidlow, C. J., Hurst, G., Masterson, D., Smith, G., Ellis, N., Clark-Carter, D., Tarvainen, M. P., Braithwaite, E. C., & Nieuwenhuijsen, M. (2021). Psycho-physiological responses of repeated exposure to natural and urban environments. *Landscape and Urban Planning*, 209, 104061. <https://doi.org/10.1016/j.landurbplan.2021.104061>
- Jorgensen, L. J., Ellis, G. D., & Ruddell, E. (2013). Fear Perceptions in Public Parks: Interactions of Environmental Concealment, the Presence of People Recreating, and Gender. *Environment and Behavior*, 45(7), 803–820. <https://doi.org/10.1177/0013916512446334>
- Joye, Y., & Dewitte, S. (2018). Nature's broken path to restoration. A critical look at Attention Restoration Theory. *Journal of Environmental Psychology*, 59, 1–8. <https://doi.org/10.1016/j.jenvp.2018.08.006>
- Jung, D., Kim, D. I., & Kim, N. (2023). Bringing nature into hospital architecture: Machine learning-based EEG analysis of the biophilia effect in virtual reality. *Journal of Environmental Psychology*, 89, 102033. <https://doi.org/10.1016/j.jenvp.2023.102033>
- Kaczynski, A. T., & Henderson, K. A. (2008). Parks and recreation settings and active living: A review of associations with physical activity function and intensity. *Journal of Physical Activity & Health*, 5(4), 619–632. <https://doi.org/10.1123/jpah.5.4.619>
- Kaczynski, A. T., Potwarka, L. R., Smale, B. J. A., & Havitz, M. E. (2009). Association of Parkland Proximity with Neighborhood and Park-based Physical Activity: Variations by Gender and Age. *Leisure Sciences*, 31(2), 174–191. <https://doi.org/10.1080/01490400802686045>
- Kalantari, S., Xu, T., Mostafavi, A., Lee, A., Barankevich, R., Boot, W., & Czaja, S. (2022). Using a Nature-based Virtual Reality Environment for Improving Mood States and Cognitive Engagement in Older Adults: A Mixed-method Feasibility Study.
- Kang, J. (2014). *Urban Sound Environment*. CRC Press. <https://doi.org/10.1201/9781482265613>
- Kaplan. (1995). The restorative benefits of nature: Toward an integrative framework. *Journal of Environmental Psychology*, 15(3), 169–182. [https://doi.org/10.1016/0272-4944\(95\)90001-2](https://doi.org/10.1016/0272-4944(95)90001-2)
- Kaplan, & Kaplan. (1989). *The Experience of Nature: A Psychological Perspective*. CUP Archive.

Kaplan, R., Bardwell, L. V., Ford, H. A., & Kaplan, S. (1996). The corporate back-40: Employee benefits of wildlife enhancement efforts on corporate land. *Human Dimensions of Wildlife*, 1(2), 1–13. <https://doi.org/10.1080/10871209609359058>

Kaplan, S., Bardwell, L. V., & Slakter, D. B. (1993). The Museum as a Restorative Environment. *Environment and Behavior*, 25(6), 725–742. <https://doi.org/10.1177/0013916593256004>

Kapteyn, A., Lee, J., Tassot, C., Vonkova, H., & Zamarro, G. (2015). Dimensions of Subjective Well-Being. *Social Indicators Research*, 123(3), 625–660. <https://doi.org/10.1007/s11205-014-0753-0>

Karmanov, D., & Hamel, R. (2008). Assessing the restorative potential of contemporary urban environment(s): Beyond the nature versus urban dichotomy. *Landscape and Urban Planning*, 86(2), 115–125. <https://doi.org/10.1016/j.landurbplan.2008.01.004>

Keeley, B. (2021). The State of the World's Children 2021. UNICEF. <https://www.unicef.org/reports/state-worlds-children-2021>

Kemperman, A., & Timmermans, H. (2014). Green spaces in the direct living environment and social contacts of the aging population. *Landscape and Urban Planning*, 129, 44–54. <https://doi.org/10.1016/j.landurbplan.2014.05.003>

Kennedy, R. S., Lane, N. E., Berbaum, K. S., & Lilienthal, M. G. (1993). Simulator Sickness Questionnaire: An Enhanced Method for Quantifying Simulator Sickness. *The International Journal of Aviation Psychology*, 3(3), 203–220. https://doi.org/10.1207/s15327108ijap0303_3

Khan, M., Amin, N., Khan, A., Imtiaz, M., Khan, F., Ahmad, I., Ali, A., & Islam, B. (2016). Plant Therapy: A Nonpharmacological and Noninvasive Treatment Approach Medically Beneficial to the Wellbeing of Hospital Patients. *Gesunde Pflanzen*, 68. <https://doi.org/10.1007/s10343-016-0377-1>

Kim, D.-W., & Im, C.-H. (2018). EEG Spectral Analysis. In C.-H. Im (Ed.), *Computational EEG Analysis: Methods and Applications* (pp. 35–53). Springer. https://doi.org/10.1007/978-981-13-0908-3_3

Kim, H.-G., Cheon, E.-J., Bai, D.-S., Lee, Y. H., & Koo, B.-H. (2018). Stress and Heart Rate Variability: A Meta-Analysis and Review of the Literature. *Psychiatry Investigation*, 15(3),

235. <https://doi.org/10.30773/pi.2017.08.17>

Kim, S.-G., Jin, T., & Fukuda, M. (2020). Spatial Resolution of fMRI Techniques. In S. Ulmer & O. Jansen (Eds.), *fMRI: Basics and Clinical Applications* (pp. 65–72). Springer International Publishing. https://doi.org/10.1007/978-3-030-41874-8_6

Kim, Y. Y., Kim, H. J., Kim, E. N., Ko, H. D., & Kim, H. T. (2005). Characteristic changes in the physiological components of cybersickness. *Psychophysiology*, 42(5), 616–625. <https://doi.org/10.1111/j.1469-8986.2005.00349.x>

Kirkbride, J. B., Anglin, D. M., Colman, I., Dykxhoorn, J., Jones, P. B., Patalay, P., Pitman, A., Soneson, E., Steare, T., Wright, T., & Griffiths, S. L. (2024). The social determinants of mental health and disorder: Evidence, prevention and recommendations. *World Psychiatry*, 23(1), 58–90. <https://doi.org/10.1002/wps.21160>

Kirschbaum, C., Hellhammer, D. H., & Fink, G. (2000). Salivary Cortisol. In *Encyclopedia of Stress* (pp. 379–384). Academic Press.

Klotz, A. C., & Bolino, M. C. (2021). Bringing the great outdoors into the workplace: The energizing effect of biophilic work design. *The Academy of Management Review*, 46(2), 231–251.

Knaust, T., Felnhofer, A., Kothgassner, O. D., Höllmer, H., Gorzka, R.-J., & Schulz, H. (2021). Exposure to virtual nature: The impact of different immersion levels on skin conductance level, heart rate, and perceived relaxation. *Virtual Reality*. <https://doi.org/10.1007/s10055-021-00595-2>

Koivisto, M., & Grassini, S. (2024). The restorative effects of mental imagery of nature: A study on subjective and physiological responses. *Journal of Environmental Psychology*, 96, 102346. <https://doi.org/10.1016/j.jenvp.2024.102346>

Konijnendijk, C., van den Bosch, M., Nielsen, A., & Maruthaveeran, S. (2013). Benefits of Urban Parks A systematic review—A Report for IFPRA.

Korpela, K., & Hartig, T. (1996). Restorative qualities of favourite places. *Journal of Environmental Psychology*, 16(3), 221–233. <https://doi.org/10.1006/jev.1996.0018>

Korpela, K. M., Ylén, M., Tyrväinen, L., & Silvennoinen, H. (2008). Determinants of restorative experiences in everyday favorite places. *Health & Place*, 14(4), 636–652. <https://doi.org/10.1016/j.healthplace.2007.10.008>

- Krapez, A., Hughes, M., & Newsome, D. (2021). Perceptions of ‘naturalness’ by urban park visitors: Insights from Perth, Western Australia. *International Journal of Geoheritage and Parks*, 9(4), 450–462. <https://doi.org/10.1016/j.ijgeop.2021.11.004>
- Krefis, A. C., Augustin, M., Schlünzen, K. H., Oßenbrügge, J., & Augustin, J. (2018). How Does the Urban Environment Affect Health and Well-Being? A Systematic Review. *Urban Science*, 2(1), Article 1. <https://doi.org/10.3390/urbansci2010021>
- Kubitz, K. A., & Pothakos, K. (1997). Does Aerobic Exercise Decrease Brain Activation? *Journal of Sport and Exercise Psychology*, 19(3), 291–301. <https://doi.org/10.1123/jsep.19.3.291>
- Kudielka, B. M., Buske-Kirschbaum, A., Hellhammer, D. H., & Kirschbaum, C. (2004). HPA axis responses to laboratory psychosocial stress in healthy elderly adults, younger adults, and children: Impact of age and gender. *Psychoneuroendocrinology*, 29(1), 83–98. [https://doi.org/10.1016/S0306-4530\(02\)00146-4](https://doi.org/10.1016/S0306-4530(02)00146-4)
- Kulkarni, S., O’Farrell, I., Erasi, M., & Kochar, M. S. (1998). Stress and hypertension. *WMJ: Official Publication of the State Medical Society of Wisconsin*, 97(11), 34–38.
- Kuper, R. (2018). Effects of Flowering, Foliation, and Autumn Colors on Preference and Restorative Potential for Designed Digital Landscape Models. *Environment and Behavior*, 52(5), 544–576. <https://doi.org/10.1177/0013916518811424>
- Kurle, C. M., Cadotte, M. W., Seo, M., Dooner, P., & Jones, H. P. (2023). Considering humans as integral components of “nature”. *Ecological Solutions and Evidence*, 4(1), e12220. <https://doi.org/10.1002/2688-8319.12220>
- Kyttä, M., Oliver, M., Ikeda, E., Ahmadi, E., Omiya, I., & Laatikainen, T. (2018). Children as urbanites: Mapping the affordances and behavior settings of urban environments for Finnish and Japanese children. *Children’s Geographies*, 16(3), 319–332. <https://doi.org/10.1080/14733285.2018.1453923>
- Lafrenz, A. J. (2022). Designing Multifunctional Urban Green Spaces: An Inclusive Public Health Framework. *International Journal of Environmental Research and Public Health*, 19(17), 10867. <https://doi.org/10.3390/ijerph191710867>
- Lahart, I., Darcy, P., Gidlow, C., & Calogiuri, G. (2019). The Effects of Green Exercise on Physical and Mental Wellbeing: A Systematic Review. *International Journal of Environmental Research and Public Health*, 16(8), Article 8. <https://doi.org/10.3390/ijerph16081352>

- Lai, K. Y., Sarkar, C., Sun, Z., & Scott, I. (2020). Are greenspace attributes associated with perceived restorativeness? A comparative study of urban cemeteries and parks in Edinburgh, Scotland. *Urban Forestry & Urban Greening*, 53, 126720.
<https://doi.org/10.1016/j.ufug.2020.126720>
- Lalanda Nico, M. (2016). Bringing life “back into life course research”: Using the life grid as a research instrument for qualitative data collection and analysis. *Quality & Quantity*, 50(5), 2107–2120. <https://doi.org/10.1007/s11135-015-0253-6>
- Largo-Wight, E., Wlyudka, P. S., Merten, J. W., & Cuvelier, E. A. (2017). Effectiveness and feasibility of a 10-minute employee stress intervention: Outdoor Booster Break. *Journal of Workplace Behavioral Health*, 32(3), 159–171.
<https://doi.org/10.1080/15555240.2017.1335211>
- Laszkiewicz, E., Kronenberg, J., Mohamed, A., Roitsch, D., & De Vreese, R. (2023). Who does not use urban green spaces and why? Insights from a comparative study of thirty-three European countries. *Landscape and Urban Planning*, 239, 104866.
<https://doi.org/10.1016/j.landurbplan.2023.104866>
- Lau, S. S. S., Leung, S. S. K., Wong, J. W. C., Lee, T. C. P., Cartwright, S. R., Wong, J. T. C., Man, J., Cheung, E., & Choi, R. P. W. (2023). Brief repeated virtual nature contact for three weeks boosts university students’ nature connectedness and psychological and physiological health during the COVID-19 pandemic: A pilot study. *Frontiers in Public Health*, 10.
<https://doi.org/10.3389/fpubh.2022.1057020>
- Laumann, K., Gärling, T., & Stormark, K. M. (2001). Rating scale measures of restorative components of environments. *Journal of Environmental Psychology*, 21(1), 31–44.
<https://doi.org/10.1006/jevp.2000.0179>
- Laumann, K., Gärling, T., & Stormark, K. M. (2003). Selective attention and heart rate responses to natural and urban environments. *Journal of Environmental Psychology*, 23(2), 125–134. [https://doi.org/10.1016/S0272-4944\(02\)00110-X](https://doi.org/10.1016/S0272-4944(02)00110-X)
- Lecic-Tosevski, D. (2019). Is urban living good for mental health? : Current Opinion in Psychiatry. 32, 204–209.
- Lederbogen, F., Kirsch, P., Haddad, L., Streit, F., Tost, H., Schuch, P., Wüst, S., Pruessner, J. C., Rietschel, M., Deuschle, M., & Meyer-Lindenberg, A. (2011). City living and urban

upbringing affect neural social stress processing in humans. *Nature*, 474(7352), 498–501.
<https://doi.org/10.1038/nature10190>

Lee, A. C. K., Jordan, H. C., & Horsley, J. (2015). Value of urban green spaces in promoting healthy living and wellbeing: Prospects for planning. *Risk Management and Healthcare Policy*, 8, 131–137. <https://doi.org/10.2147/RMHP.S61654>

Lee, H. J., & Lee, D. K. (2019). Do Sociodemographic Factors and Urban Green Space Affect Mental Health Outcomes Among the Urban Elderly Population? *International Journal of Environmental Research and Public Health*, 16(5), Article 5.
<https://doi.org/10.3390/ijerph16050789>

Lee, M., Kim, E., Choe, J., Choi, S., Ha, S., & Kim, G. (2022). Psychological Effects of Green Experiences in a Virtual Environment: A Systematic Review. *Forests*, 13(10), Article 10.
<https://doi.org/10.3390/f13101625>

Lee, R. M., Draper, M., & Lee, S. (2001). Social connectedness, dysfunctional interpersonal behaviors, and psychological distress: Testing a mediator model. *Journal of Counseling Psychology*, 48(3), 310–318. <https://doi.org/10.1037/0022-0167.48.3.310>

Lemyre, A., & Messina, J. P. (2023). Greenspace use during the COVID-19 pandemic: A longitudinal population mobility study in the United Kingdom. *Environmental Research*, 239, 117360. <https://doi.org/10.1016/j.envres.2023.117360>

Lent, R. W. (2004). Toward a Unifying Theoretical and Practical Perspective on Well-Being and Psychosocial Adjustment. *Journal of Counseling Psychology*, 51(4), 482–509.
<https://doi.org/10.1037/0022-0167.51.4.482>

Lepore, S.J. (2012). Crowding: Effects on Health and Behavior. *Encyclopedia of Human Behavior* (Second Edition). 638-643.

Levy-Storms, L., Chen, L., & Loukaitou-Sideris, A. (2018). Older Adults' Needs and Preferences for Open Space and Physical Activity in and Near Parks: A Systematic Review. *Journal of Aging and Physical Activity*, 26(4), 682–696. <https://doi.org/10.1123/japa.2016-0354>

Liang, L., Gobeawan, L., Lau, S.-K., Lin, E. S., & Ang, K. K. (2024). Urban Green Spaces and Mental Well-Being: A Systematic Review of Studies Comparing Virtual Reality versus Real Nature. *Future Internet*, 16(6), Article 6. <https://doi.org/10.3390/fi16060182>

- Linton, M.-J., Dieppe, P., & Medina-Lara, A. (2016). Review of 99 self-report measures for assessing well-being in adults: Exploring dimensions of well-being and developments over time. *BMJ Open*, 6(7), e010641. <https://doi.org/10.1136/bmjopen-2015-010641>
- Lis, A., & Iwankowski, P. (2021). Where do we want to see other people while relaxing in a city park? Visual relationships with park users and their impact on preferences, safety and privacy. *Journal of Environmental Psychology*, 73, 101532. <https://doi.org/10.1016/j.jenvp.2020.101532>
- Liszio, S., Graf, L., & Masuch, M. (2018). The Relaxing Effect of Virtual Nature: Immersive Technology Provides Relief in Acute Stress Situations. 16, 87–93.
- Liszio, S., & Masuch, M. (2019). Interactive Immersive Virtual Environments Cause Relaxation and Enhance Resistance to Acute Stress. *Annual Review of CyberTherapy and Telemedicine*, 17, 65.
- Little, H., & Wyver, S. (2008). Outdoor Play: Does Avoiding the Risks Reduce the Benefits? *Australasian Journal of Early Childhood*, 33(2), 33–40. <https://doi.org/10.1177/183693910803300206>
- Liu, Y., Hu, M., & Zhao, B. (2019). Audio-visual interactive evaluation of the forest landscape based on eye-tracking experiments. *Urban Forestry & Urban Greening*, 46, 126476. <https://doi.org/10.1016/j.ufug.2019.126476>
- Lizée, M.-H., Manel, S., Mauffrey, J.-F., Tatoni, T., & Deschamps-Cottin, M. (2012). Matrix configuration and patch isolation influences override the species–area relationship for urban butterfly communities. *Landscape Ecology*, 27(2), 159–169. <https://doi.org/10.1007/s10980-011-9651-x>
- Lo, A. Y. H., & Jim, C. Y. (2010). Differential community effects on perception and use of urban greenspaces. *Cities*, 27(6), 430–442. <https://doi.org/10.1016/j.cities.2010.07.001>
- Lok, I., & Dunn, E. (2023). The UBC State Social Connection Scale: Factor Structure, Reliability, and Validity. *Social Psychological and Personality Science*, 14(7), 835–844. <https://doi.org/10.1177/19485506221132090>
- Lomas, T., Ivtzan, I., & Fu, C. H. Y. (2015). A systematic review of the neurophysiology of mindfulness on EEG oscillations. *Neuroscience & Biobehavioral Reviews*, 57, 401–410. <https://doi.org/10.1016/j.neubiorev.2015.09.018>
- Loukaitou-Sideris, A., & Sideris, A. (2009). What Brings Children to the Park? Analysis and

Measurement of the Variables Affecting Children's Use of Parks. *Journal of the American Planning Association*, 76(1), 89–107. <https://doi.org/10.1080/01944360903418338>

Louv, R. (2008). *Last Child in the Woods: Saving Our Children From Nature-Deficit Disorder*. Algonquin Books.

Lyons, R., Colbert, A., Browning, M., & Jakub, K. (2022). Urban greenspace use among adolescents and young adults: An integrative review. *Public Health Nursing*, 39(3), 700–718. <https://doi.org/10.1111/phn.13010>

Ma, B., Zhou, T., Lei, S., Wen, Y., & Htun, T. T. (2019). Effects of urban green spaces on residents' well-being. *Environment, Development and Sustainability*, 21(6), 2793–2809. <https://doi.org/10.1007/s10668-018-0161-8>

Ma, J., Lin, P., & Williams, J. (2024). Effectiveness of nature-based walking interventions in improving mental health in adults: A systematic review. *Current Psychology*, 43(11), 9521–9539. <https://doi.org/10.1007/s12144-023-05112-z>

Maas, J., Verheij, R. A., Groenewegen, P. P., Vries, S. de, & Spreeuwenberg, P. (2006). Green space, urbanity, and health: How strong is the relation? *Journal of Epidemiology & Community Health*, 60(7), 587–592. <https://doi.org/10.1136/jech.2005.043125>

Machado, Y. S., Schubert, P. M. P., Albuquerque, D. da S., & Kuhnen, A. (2016). Brincadeiras infantis e natureza: Investigação da interação criança-natureza em parques verdes urbanos. *Temas em Psicologia*, 24(2), 655–667. <https://doi.org/10.9788/TP2016.2-14Pt>

Macintyre, V. G., Cotterill, S., Anderson, J., Phillipson, C., Benton, J. S., & French, D. P. (2019). “I Would Never Come Here Because I’ve Got My Own Garden”: Older Adults’ Perceptions of Small Urban Green Spaces. *International Journal of Environmental Research and Public Health*, 16(11), Article 11. <https://doi.org/10.3390/ijerph16111994>

Mak, B. K. L., & Jim, C. Y. (2018). Examining fear-evoking factors in urban parks in Hong Kong. *Landscape and Urban Planning*, 171, 42–56. <https://doi.org/10.1016/j.landurbplan.2017.11.012>

Manohare, M., Rajasekar, E., & Parida, M. (2023). Analysing the Change in Brain Waves due to Heterogeneous Road Traffic Noise Exposure Using Electroencephalography Measurements. *Noise & Health*, 25(116), 36. https://doi.org/10.4103/nah.nah_58_22

Markevych, I., Schoierer, J., Hartig, T., Chudnovsky, A., Hystad, P., Dzhambov, A. M., de Vries,

- S., Triguero-Mas, M., Brauer, M., Nieuwenhuijsen, M. J., Lupp, G., Richardson, E. A., AstellBurt, T., Dimitrova, D., Feng, X., Sadeh, M., Standl, M., Heinrich, J., & Fuertes, E. (2017). Exploring pathways linking greenspace to health: Theoretical and methodological guidance. *Environmental Research*, 158, 301–317. <https://doi.org/10.1016/j.envres.2017.06.028>
- Marselle, M. R., Hartig, T., Cox, D. T. C., de Bell, S., Knapp, S., Lindley, S., Triguero-Mas, M., Böhning-Gaese, K., Braubach, M., Cook, P. A., de Vries, S., Heintz-Buschart, A., Hofmann, M., Irvine, K. N., Kabisch, N., Kolek, F., Kraemer, R., Markevych, I., Martens, D., ... Bonn, A. (2021). Pathways linking biodiversity to human health: A conceptual framework. *Environment International*, 150, 106420. <https://doi.org/10.1016/j.envint.2021.106420>
- Marteau, T. M., & Bekker, H. (1992). The development of a six-item short-form of the state scale of the Spielberger State—Trait Anxiety Inventory (STAI). *British Journal of Clinical Psychology*, 31(3), 301–306. <https://doi.org/10.1111/j.2044-8260.1992.tb00997.x>
- Martínez-Soto, J., de la Fuente Suárez, L. A., & Ruiz-Correa, S. (2021). Exploring the Links Between Biophilic and Restorative Qualities of Exterior and Interior Spaces in Leon, Guanajuato, Mexico. *Frontiers in Psychology*, 12. <https://doi.org/10.3389/fpsyg.2021.717116>
- Martínez-Soto, J., Gonzales-Santos, L., Barrios, F. A., & Lena, M. E. M.-L. (2014). Affective and Restorative Valences for Three Environmental Categories. *Perceptual and Motor Skills*, 119(3), 901–923. <https://doi.org/10.2466/24.50.PMS.119c29z4>
- Maruthaveeran, S., & van den Bosch, C. C. K. (2014). A socio-ecological exploration of fear of crime in urban green spaces – A systematic review. *Urban Forestry & Urban Greening*, 13(1), 1–18. <https://doi.org/10.1016/j.ufug.2013.11.006>
- Maskey, M., Lowry, J., Rodgers, J., McConachie, H., & Parr, J. R. (2014). Reducing Specific Phobia/Fear in Young People with Autism Spectrum Disorders (ASDs) through a Virtual Reality Environment Intervention. *PLOS ONE*, 9(7), 12.
- Mason, S. (2018). Publications in the doctoral thesis: Challenges for doctoral candidates, supervisors, examiners and administrators. *Higher Education Research & Development*, 37(6), 1231–1244. <https://doi.org/10.1080/07294360.2018.1462307>
- Massoni, E. S., Barton, D. N., Rusch, G. M., & Gundersen, V. (2018). Bigger, more diverse and better? Mapping structural diversity and its recreational value in urban green spaces.

Ecosystem Services, 31(PC), 502–516.

Mastandrea, S., Fagioli, S., & Biasi, V. (2019). Art and Psychological Well-Being: Linking the Brain to the Aesthetic Emotion. *Frontiers in Psychology*, 10.

<https://www.frontiersin.org/articles/10.3389/fpsyg.2019.00739>

Matsuda, S., Yamaguchi, T., Okada, K., Gotouda, A., & Mikami, S. (2012). Day-to-day variations in salivary cortisol measurements. *Journal of Prosthodontic Research*, 56(1), 37–41. <https://doi.org/10.1016/j.jpor.2011.04.004>

Matthews, G., Jones, D. M., & Chamberlain, A. G. (1990). Refining the measurement of mood: The UWIST Mood Adjective Checklist. *British Journal of Psychology*, 81(1), 17–42. <https://doi.org/10.1111/j.2044-8295.1990.tb02343.x>

Mavros, P., J Wälti, M., Nazemi, M., Ong, C. H., & Hölscher, C. (2022). A mobile EEG study on the psychophysiological effects of walking and crowding in indoor and outdoor urban environments. *Scientific Reports*, 12(1), 18476. <https://doi.org/10.1038/s41598-022-20649y>

Mayer, F. S., & Frantz, C. M. (2004). The connectedness to nature scale: A measure of individuals' feeling in community with nature. *Journal of Environmental Psychology*, 24(4), 503–515. <https://doi.org/10.1016/j.jenvp.2004.10.001>

McAllister, K., McBeth, A., & Galway, N. (2022). Autism spectrum condition and the built environment. *Cities & Health*, 6(6), 1164–1178. <https://doi.org/10.1080/23748834.2022.2139210>

McCormack, G. R., Rock, M., Toohey, A. M., & Hignell, D. (2010). Characteristics of urban parks associated with park use and physical activity: A review of qualitative research. *Health & Place*, 16(4), 712–726. <https://doi.org/10.1016/j.healthplace.2010.03.003>

McCormick, R. (2017). Does Access to Green Space Impact the Mental Well-being of Children: A Systematic Review. *Journal of Pediatric Nursing*, 37, 3–7. <https://doi.org/10.1016/j.pedn.2017.08.027>

McDaid, D., Park, A.-L., Davidson, G., John, A., Knifton, L., McDaid, S., Morton, A., Thorpe, L., & Wilson, N. (2022). The economic case for investing in the prevention of mental health conditions in the UK. Mental Health Foundation.

- McDermott, E. J., Metsomaa, J., Belardinelli, P., Grosse-Wentrup, M., Ziemann, U., & Zrenner, C. (2021). Predicting motor behavior: An efficient EEG signal processing pipeline to detect brain states with potential therapeutic relevance for VR-based neurorehabilitation. *Virtual Reality*. <https://doi.org/10.1007/s10055-021-00538-x>
- McGrath, C., Palmgren, P. J., & Liljedahl, M. (2019). Twelve tips for conducting qualitative research interviews. *Medical Teacher*, 41(9), 1002–1006. <https://doi.org/10.1080/0142159X.2018.1497149>
- McGrath, L. J., Hopkins, W. G., & Hinckson, E. A. (2015). Associations of objectively measured built-environment attributes with youth moderate-vigorous physical activity: A systematic review and meta-analysis. *Sports Medicine (Auckland, N.Z.)*, 45(6), 841–865. <https://doi.org/10.1007/s40279-015-0301-3>
- McKinney, M. L., & VerBerkmoes, A. (2020). Beneficial Health Outcomes of Natural Green Infrastructure in Cities. *Current Landscape Ecology Reports*, 5(2), 35–44. <https://doi.org/10.1007/s40823-020-00051-y>
- McMahan, E. A., & Estes, D. (2015). The effect of contact with natural environments on positive and negative affect: A meta-analysis. *The Journal of Positive Psychology*, 10(6), 507–519. <https://doi.org/10.1080/17439760.2014.994224>
- Menardo, E., Brondino, M., Hall, R., & Pasini, M. (2021). Restorativeness in Natural and Urban Environments: A Meta-Analysis. *Psychological Reports*, 124(2), 417–437. <https://doi.org/10.1177/0033294119884063>
- Mental Health Foundation. (2018). Stress: Are we coping? Mental Health Foundation. <https://www.mentalhealth.org.uk/explore-mental-health/publications/stress-are-wecoping-report>
- Mertens, L., Cauwenberg, J. V., Veitch, J., Deforche, B., & Dyck, D. V. (2019). Differences in park characteristic preferences for visitation and physical activity among adolescents: A latent class analysis. *PLOS ONE*, 14(3), e0212920. <https://doi.org/10.1371/journal.pone.0212920>
- Meteyard, L., & Davies, R. A. I. (2020). Best practice guidance for linear mixed-effects models in psychological science. *Journal of Memory and Language*, 112, 104092. <https://doi.org/10.1016/j.jml.2020.104092>

- Mifsud, K. R., & Reul, J. M. H. M. (2018). Mineralocorticoid and glucocorticoid receptor-mediated control of genomic responses to stress in the brain. *Stress (Amsterdam, Netherlands)*, 21(5), 389–402. <https://doi.org/10.1080/10253890.2018.1456526>
- Millets. (2024). Eco-Friendly Destinations. https://www.millets.co.uk/blog/eco-friendlydestinations?sv_campaign_id=78888&sv_tax1=affiliate&sv_tax2=&sv_tax3=Skimlinks&sv_tax4=bristolpost.co.uk&sv_affiliate_id=78888&awc=1521_1727613719_bca97d6a0bf589a3ed0601c656e60665&utm_source=affiliate78888&utm_medium=Sub+Networks&utm_campaign=Skimlinks
- Miret, M., Caballero, F. F., Olaya, B., Koskinen, S., Naidoo, N., Tobiasz-Adamczyk, B., Leonardi, M., Haro, J. M., Chatterji, S., & Ayuso-Mateos, J. L. (2017). Association of experienced and evaluative well-being with health in nine countries with different income levels: A cross-sectional study. *Globalization and Health*, 13(1), 65. <https://doi.org/10.1186/s12992-017-0290-0>
- Mitchell, R., Astell-Burt, T., & Richardson, E. A. (2011). A comparison of green space indicators for epidemiological research. *J Epidemiol Community Health*, 65(10), 853–858. <https://doi.org/10.1136/jech.2010.119172>
- Morse, J. M. (2000). Determining Sample Size. *Qualitative Health Research*, 10(1), 3–5. <https://doi.org/10.1177/104973200129118183>
- Mostajeran, F., Krzikawski, J., Steinicke, F., & Kühn, S. (2021). Effects of exposure to immersive videos and photo slideshows of forest and urban environments. *Scientific Reports*, 11(1), 3994. <https://doi.org/10.1038/s41598-021-83277-y>
- Mueller, N., Rojas, -Rueda David, Basaga, ña X., Cirach, M., Cole, -Hunter Tom, Dadvand, P., Donaire, -Gonzalez David, Foraster, M., Gascon, M., Martinez, D., Tonne, C., Triguero, -Mas Margarita, Valent, ín A., & Nieuwenhuijsen, M. (2017). Urban and Transport Planning Related Exposures and Mortality: A Health Impact Assessment for Cities. *Environmental Health Perspectives*, 125(1), 89–96. <https://doi.org/10.1289/EHP220>
- Nadkarni, N. M., Thys, T. M., Ruff, J. S., Anholt, A., Treviño, J., & Yeo, S. K. (2021). Providing Virtual Nature Experiences to Incarcerated Men Reduces Stress and Increases Interest in the Environment. *Ecopsychology*, 13(2), 71–83. <https://doi.org/10.1089/eco.2020.0043>

- Nath, T. K., Zhe Han, S. S., & Lechner, A. M. (2018). Urban green space and well-being in Kuala Lumpur, Malaysia. *Urban Forestry & Urban Greening*, 36, 34–41.
<https://doi.org/10.1016/j.ufug.2018.09.013>
- Natural England. (2020). The People and Nature Survey For England—PANS001.
<https://publications.naturalengland.org.uk/publication/6382837173583872>
- Navarrete-Hernandez, P., & Laffan, K. (2019). A greener urban environment: Designing green infrastructure interventions to promote citizens' subjective wellbeing. *Landscape and Urban Planning*, 191, 103618. <https://doi.org/10.1016/j.landurbplan.2019.103618>
- Neal, S., Bennett, K., Jones, H., Cochrane, A., & Mohan, G. (2015). Multiculture and Public Parks: Researching Super-diversity and Attachment in Public Green Space. *Population, Space and Place*, 21(5), 463–475. <https://doi.org/10.1002/psp.1910>
- Neale, C., Aspinall, P., Roe, J., Tilley, S., Mavros, P., Cinderby, S., Coyne, R., Thin, N., & Ward Thompson, C. (2020). The impact of walking in different urban environments on brain activity in older people. *Cities & Health*, 4(1), 94–106.
<https://doi.org/10.1080/23748834.2019.1619893>
- Neale, C., Lopez, S., & Roe, J. (2021). Psychological Restoration and the Effect of People in Nature and Urban Scenes: A Laboratory Experiment. *Sustainability*, 13(11), Article 11.
<https://doi.org/10.3390/su13116464>
- Neill, C., Gerard, J., & Arbuthnott, K. D. (2019). Nature contact and mood benefits: Contact duration and mood type. *The Journal of Positive Psychology*, 14(6), 756–767.
<https://doi.org/10.1080/17439760.2018.1557242>
- Nelischer, C., & Loukaitou-Sideris, A. (2023). Intergenerational Public Space Design and Policy: A Review of the Literature. *Journal of Planning Literature*, 38(1), 19–32.
<https://doi.org/10.1177/08854122221092175>
- Nelischer, C., Loukaitou-Sideris, A., & Wendel, G. (2024). Caring public space: Advancing justice through intergenerational public space design and planning. *Journal of Urban Affairs*, 0(0), 1–20. <https://doi.org/10.1080/07352166.2023.2291074>
- Nguyen, L., & Walters, J. (2024). Benefits of nature exposure on cognitive functioning in children and adolescents: A systematic review and meta-analysis. *Journal of Environmental Psychology*, 96, 102336. <https://doi.org/10.1016/j.jenvp.2024.102336>

- NHS. (2024a). Age—NHS digital service manual. Nhs.Uk. <https://service-manual.nhs.uk>
- NHS. (2024b). High blood pressure. Nhs.Uk. <https://www.nhs.uk/conditions/high-bloodpressure/>
- NHS England. (2022). Research demand signalling: National Mental Health Programme. https://www.england.nhs.uk/aac/wp-content/uploads/sites/50/2022/09/B1482_researchdemand-signalling-national-mental-health-programme_september-2022.pdf
- Niedermeier, M., Einwanger, J., Hartl, A., & Kopp, M. (2017). Affective responses in mountain hiking—A randomized crossover trial focusing on differences between indoor and outdoor activity. *PLOS ONE*, 12(5), e0177719. <https://doi.org/10.1371/journal.pone.0177719>
- Niemann, H., Bonnefoy, X., Braubach, M., Hecht, K., Maschke, C., Rodrigues, C., & Robbel, N. (2006). Noise-induced annoyance and morbidity results from the pan-European LARES study. *Noise and Health*, 8(31), 63. <https://doi.org/10.4103/1463-1741.33537>
- Nieuwenhuijsen, M. J., Khreis, H., Triguero-Mas, M., Gascon, M., & Dadvand, P. (2017). Fifty Shades of Green: Pathway to Healthy Urban Living. *Epidemiology*, 28(1), 63. <https://doi.org/10.1097/EDE.0000000000000549>
- Noe, E. E., & Stolte, O. (2023). Dwelling in the city: A qualitative exploration of the humannature relationship in three types of urban greenspace. *Landscape and Urban Planning*, 230, 104633. <https://doi.org/10.1016/j.landurbplan.2022.104633>
- Nordh, H. (2010). Restorative components of small urban parks [Doctoral thesis, Norwegian University of Life Sciences, Ås]. <https://nmbu.brage.unit.no/nmbuxmlui/handle/11250/2431920>
- Nordh, H. (2012). Quantitative methods of measuring restorative components in urban public parks. *Journal of Landscape Architecture*, 7(1), 46–53. <https://doi.org/10.1080/18626033.2012.693780>
- Nordh, H., Alalouch, C., & Hartig, T. (2011). Assessing restorative components of small urban parks using conjoint methodology. *Urban Forestry & Urban Greening*, 10(2), 95–103. <https://doi.org/10.1016/j.ufug.2010.12.003>

- Nordh, H., Evensen, K. H., & Skår, M. (2017). A peaceful place in the city—A qualitative study of restorative components of the cemetery. *Landscape and Urban Planning*, 167, 108–117. <https://doi.org/10.1016/j.landurbplan.2017.06.004>
- Nordh, H., Hartig, T., Hagerhall, C. M., & Fry, G. (2009). Components of small urban parks that predict the possibility for restoration. *Urban Forestry & Urban Greening*, 8(4), 225–235. <https://doi.org/10.1016/j.ufug.2009.06.003>
- Nordh, H., & Østby, K. (2013). Pocket parks for people – A study of park design and use. *Urban Forestry & Urban Greening*, 12(1), 12–17. <https://doi.org/10.1016/j.ufug.2012.11.003>
- Nukarinen, T., Istance, H. O., Rantala, J., Mäkelä, J., Korpela, K., Ronkainen, K., Surakka, V., & Raisamo, R. (2020). Physiological and Psychological Restoration in Matched Real and Virtual Natural Environments. *Extended Abstracts of the 2020 CHI Conference on Human Factors in Computing Systems*, 1–8. <https://doi.org/10.1145/3334480.3382956>
- Ode Sang, Å., Knez, I., Gunnarsson, B., & Hedblom, M. (2016). The effects of naturalness, gender, and age on how urban green space is perceived and used. *Urban Forestry & Urban Greening*, 18, 268–276. <https://doi.org/10.1016/j.ufug.2016.06.008>
- OECD. (2013). *OECD Guidelines on Measuring Subjective Well-being*. Organisation for Economic Co-operation and Development. https://www.oecd-ilibrary.org/economics/oecdguidelines-on-measuring-subjective-well-being_9789264191655-en
- Office for Health Improvement & Disparities. (2022). *Wellbeing and mental health: Applying All Our Health*. Government Office for Health Improvement & Disparities. <https://www.gov.uk/government/publications/wellbeing-in-mental-health-applying-all-ourhealth/wellbeing-in-mental-health-applying-all-our-health>
- Office for National Statistics. (2020). *Young people's well-being in the UK* - Office for National Statistics. <https://www.ons.gov.uk/peoplepopulationandcommunity/wellbeing/bulletins/youngpeoplewellbeingintheuk/2020>
- Office for National Statistics. (2021). *How has lockdown changed our relationship with nature?* - Office for National Statistics.

<https://www.ons.gov.uk/economy/environmentalaccounts/articles/howhaslockdownchangedourrelationshipwithnature/2021-04-26>

Office for National Statistics. (2022). Ethnic group, England and Wales—Office for National Statistics (pp. 1–9) [Statistical bulletin].

<https://www.ons.gov.uk/peoplepopulationandcommunity/culturalidentity/ethnicity/bulletins/ethnicgroupenglandandwales/census2021>

Ogundele, M. O. (2018). Behavioural and emotional disorders in childhood: A brief overview for paediatricians. *World Journal of Clinical Pediatrics*, 7(1), 9–26.

<https://doi.org/10.5409/wjcp.v7.i1.9>

Oh, H., & Son, W. (2022). Cybersickness and Its Severity Arising from Virtual Reality Content: A Comprehensive Study. *Sensors (Basel, Switzerland)*, 22(4), 1314.

<https://doi.org/10.3390/s22041314>

Ohly, H., White, M. P., Wheeler, B. W., Bethel, A., Ukoumunne, O. C., Nikolaou, V., & Garside, R. (2016). Attention Restoration Theory: A systematic review of the attention restoration potential of exposure to natural environments. *Journal of Toxicology and Environmental Health, Part B*, 19(7), 305–343. <https://doi.org/10.1080/10937404.2016.1196155>

Öhrström, E., Skånberg, A., Svensson, H., & Gidlöf-Gunnarsson, A. (2006). Effects of road traffic noise and the benefit of access to quietness. *Journal of Sound and Vibration*, 295(1), 40–59. <https://doi.org/10.1016/j.jsv.2005.11.034>

Ojala, A., Neuvonen, M., Kurkilahti, M., Leinikka, M., Huotilainen, M., & Tyrväinen, L. (2022). Short virtual nature breaks in the office environment can restore stress: An experimental study. *Journal of Environmental Psychology*, 84, 101909.

<https://doi.org/10.1016/j.jenvp.2022.101909>

Okkels, N., Kristiansen, C. B., Munk-Jørgensen, P., & Sartorius, N. (2018). Urban mental health: Challenges and perspectives. *Current Opinion in Psychiatry*, 31(3), 258.

<https://doi.org/10.1097/YCO.0000000000000413>

Olafsdottir, G., Cloke, P., Schulz, A., van Dyck, Z., Eysteinnsson, T., Thorleifsdottir, B., & Vögele, C. (2020). Health Benefits of Walking in Nature: A Randomized Controlled Study Under Conditions of Real-Life Stress. *Environment and Behavior*, 52(3), 248–274.

<https://doi.org/10.1177/0013916518800798>

Oldenburg, R. (1989). *The Great Good Place: Cafés, Coffee Shops, Community Centers, Beauty Parlors, General Stores, Bars, Hangouts and how they Get you through the Day* (p. p). Paragon House.

Oliffe, J. L., Kelly, M. T., Gonzalez Montaner, G., & Yu Ko, W. F. (2021). Zoom Interviews: Benefits and Concessions. *International Journal of Qualitative Methods*, 20, 16094069211053522. <https://doi.org/10.1177/16094069211053522>

O'Reilly, M., & Parker, N. (2013). 'Unsatisfactory Saturation': A critical exploration of the notion of saturated sample sizes in qualitative research. *Qualitative Research*, 13(2), 190–197. <https://doi.org/10.1177/1468794112446106>

Oswald, L. M., Zandi, P., Nestadt, G., Potash, J. B., Kalaydjian, A. E., & Wand, G. S. (2006). Relationship between Cortisol Responses to Stress and Personality. *Neuropsychopharmacology*, 31(7), 1583–1591. <https://doi.org/10.1038/sj.npp.1301012>

Ouellette, P., Kaplan, R., & Kaplan, S. (2005). The monastery as a restorative environment. *Journal of Environmental Psychology*, 25(2), 175–188. <https://doi.org/10.1016/j.jenvp.2005.06.001>

Packer, J., & Bond, N. (2010). Museums as Restorative Environments. *Curator: The Museum Journal*, 53(4), 421–436. <https://doi.org/10.1111/j.2151-6952.2010.00044.x>

Pain, R. (2005). Intergenerational Relations and Practice in the Development of Sustainable Communities. <https://docslib.org/doc/2082397/intergenerational-relations-and-practice-inthe-development-of-sustainable-communities>

Paletta, L., Schüssler, S., Kober, S. E., Zweytik, E., Steiner, J., Andreu, J.-P., Fuhrmann, F., Pszeida, M., Dini, A., Grabher, A., Taberhofer, A., Staubmann, W. L., Draxler, T. L., Lampl, C. L., Mayr, M. L., Kölbl, G. L., & Wood, G. L. (2020). Virtual reality–based mindfulness training, sensory activation and mental assessment in dementia care. *Alzheimer's & Dementia*, 16(S7), e047344. <https://doi.org/10.1002/alz.047344>

Parkinson, S., Eatough, V., Holmes, J., Stapley, E., & Midgley, N. (2016). Framework analysis: A worked example of a study exploring young people's experiences of depression. *Qualitative Research in Psychology*, 13(2), 109–129. <https://doi.org/10.1080/14780887.2015.1119228>

Passchier-Vermeer, W., & Passchier, W. F. (2000). Noise exposure and public health.

Environmental Health Perspectives, 108(suppl 1), 123–131.

<https://doi.org/10.1289/ehp.00108s1123>

Patel, V., Saxena, S., Lund, C., Thornicroft, G., Baingana, F., Bolton, P., Chisholm, D., Collins, P. Y., Cooper, J. L., Eaton, J., Herrman, H., Herzallah, M. M., Huang, Y., Jordans, M. J. D., Kleinman, A., Medina-Mora, M. E., Morgan, E., Niaz, U., Omigbodun, O., ... Unützer, J. (2018). The Lancet Commission on global mental health and sustainable development. *The Lancet*, 392(10157), 1553–1598. [https://doi.org/10.1016/S0140-6736\(18\)31612-X](https://doi.org/10.1016/S0140-6736(18)31612-X)

Patil, R. R. (2014). Urbanization as a Determinant of Health: A Socioepidemiological Perspective. *Social Work in Public Health*, 29(4), 335–341. <https://doi.org/10.1080/19371918.2013.821360>

Payne, L. L., Mowen, A. J., & Orsega-Smith, E. (2002). An Examination of Park Preferences and Behaviors Among Urban Residents: The Role of Residential Location, Race, and Age. *Leisure Sciences*, 24(2), 181–198. <https://doi.org/10.1080/01490400252900149>

Peen, J., Schoevers, R. A., Beekman, A. T., & Dekker, J. (2010). The current status of urbanrural differences in psychiatric disorders. *Acta Psychiatrica Scandinavica*, 121(2), 84–93. <https://doi.org/10.1111/j.1600-0447.2009.01438.x>

Peng, C., Ouyang, Z., Wang, M., Chen, W., & Jiao, W. (2012). Vegetative cover and PAHs accumulation in soils of urban green space. *Environmental Pollution*, 161, 36–42. <https://doi.org/10.1016/j.envpol.2011.09.027>

Peschardt, K. K., Schipperijn, J., & Stigsdotter, U. K. (2012). Use of Small Public Urban Green Spaces (SPUGS). *Urban Forestry & Urban Greening*, 11(3), 235–244. <https://doi.org/10.1016/j.ufug.2012.04.002>

Peter, S., & Park, L. S.-C. (2018). Changing research methodology: Two case studies of Critical Realism informing social work doctoral research. *Aotearoa New Zealand Social Work*, 30(1), Article 1. <https://doi.org/10.11157/anzswj-vol30iss1id426>

Peters, K., Elands, B., & Buijs, A. (2010). Social interactions in urban parks: Stimulating social cohesion? *Urban Forestry & Urban Greening*, 9(2), 93–100. <https://doi.org/10.1016/j.ufug.2009.11.003>

Petukhov, I. V., Glazyrin, A. E., Gorokhov, A. V., Steshina, L. A., & Tanryverdiev, I. O. (2020). Being present in a real or virtual world: A EEG study. *International Journal of Medical Informatics*, 136, 103977. <https://doi.org/10.1016/j.ijmedinf.2019.103977>

- Pheasant, R. J., Fisher, M. N., Watts, G. R., Whitaker, D. J., & Horoshenkov, K. V. (2010). The importance of auditory-visual interaction in the construction of 'tranquil space'. *Journal of Environmental Psychology*, 30(4), 501–509. <https://doi.org/10.1016/j.jenvp.2010.03.006>
- Polko, P., & Kimic, K. (2022). Gender as a factor differentiating the perceptions of safety in urban parks. *Ain Shams Engineering Journal*, 13(3), 101608. <https://doi.org/10.1016/j.asej.2021.09.032>
- Portman, M. E., Natapov, A., & Fisher-Gewirtzman, D. (2015). To go where no man has gone before: Virtual reality in architecture, landscape architecture and environmental planning. *Computers, Environment and Urban Systems*, 54, 376–384. <https://doi.org/10.1016/j.compenvurbsys.2015.05.001>
- Pretty, J., Peacock, J., Sellens, M., & Griffin, M. (2005). The mental and physical health outcomes of green exercise. *International Journal of Environmental Health Research*, 15(5), 319–337. <https://doi.org/10.1080/09603120500155963>
- Pyle, R. M. (1993). *The thunder tree: Lessons from an urban wildland*. Houghton Mifflin.
- Qin, Y. (2020). Urban Flooding Mitigation Techniques: A Systematic Review and Future Studies. *Water*, 12(12), Article 12. <https://doi.org/10.3390/w12123579>
- Queensland Brain Institute. (2023, July 31). Half of World's Population Will Experience a Mental Health Disorder | Harvard Medical School. Harvard Medical School. <https://hms.harvard.edu/news/half-worlds-population-will-experience-mental-healthdisorder>
- Ramachandran, A., Mary, S., Yamuna, A., Murugesan, N., & Snehalatha, C. (2008). High Prevalence of Diabetes and Cardiovascular Risk Factors Associated With Urbanization in India. *Diabetes Care*, 31(5), 893–898. <https://doi.org/10.2337/dc07-1207>
- Ratcliffe, E. (2015). Restorative perceptions and outcomes associated with listening to birds. [PhD Thesis, University of Surrey]. <https://openresearch.surrey.ac.uk/esploro/outputs/doctoral/Restorative-perceptions-andoutcomes-associated-with/99515682602346>
- Ratcliffe, E. (2021a). Sound and Soundscape in Restorative Natural Environments: A Narrative Literature Review. *Frontiers in Psychology*, 12, 570563. <https://doi.org/10.3389/fpsyg.2021.570563>

Ratcliffe, E. (2021b). Toward a better understanding of pleasant sounds and soundscapes in urban settings. *Cities & Health*, 5(1–2), 82–85.

<https://doi.org/10.1080/23748834.2019.1693776>

Ratcliffe, E., Gatersleben, B., & Sowden, P. T. (2013). Bird sounds and their contributions to perceived attention restoration and stress recovery. *Journal of Environmental Psychology*, 36, 221–228. <https://doi.org/10.1016/j.jenvp.2013.08.004>

Ratcliffe, E., Gatersleben, B., & Sowden, P. T. (2016). Associations with bird sounds: How do they relate to perceived restorative potential? *Journal of Environmental Psychology*, 47, 136–144. <https://doi.org/10.1016/j.jenvp.2016.05.009>

Ratcliffe, E., & Korpela, K. M. (2016). Memory and place attachment as predictors of imagined restorative perceptions of favourite places. *Journal of Environmental Psychology*, 48, 120–130. <https://doi.org/10.1016/j.jenvp.2016.09.005>

Ratcliffe, E., Ogunbode, C., Wilkie, S., Jones, C. R., Devine-Wright, P., Uzzell, D., Canter, D., Korpela, K., Pinto de Carvalho, L., & Staats, H. (2024). On the importance of qualitative research in environmental psychology. *Journal of Environmental Psychology*, 93, 102199. <https://doi.org/10.1016/j.jenvp.2023.102199>

Reason, J. T., & Brand, J. J. (1975). *Motion sickness* (pp. vii, 310). Academic Press.

Recio, A., Linares, C., Banegas, J. R., & Díaz, J. (2016). Road traffic noise effects on cardiovascular, respiratory, and metabolic health: An integrative model of biological mechanisms. *Environmental Research*, 146, 359–370.

<https://doi.org/10.1016/j.envres.2015.12.036>

Reece, R., Bornioli, A., Bray, I., & Alford, C. (2022). Exposure to Green and Historic Urban Environments and Mental Well-Being: Results from EEG and Psychometric Outcome Measures. *International Journal of Environmental Research and Public Health*, 19(20), Article 20. <https://doi.org/10.3390/ijerph192013052>

Reece, R., Bornioli, A., Bray, I., Newbutt, N., Satenstein, D., & Alford, C. (2022). Exposure to Green, Blue and Historic Environments and Mental Well-Being: A Comparison between Virtual Reality Head-Mounted Display and Flat-Screen Exposure. *International Journal of Environmental Research and Public Health*, 19(15), 9457.

<https://doi.org/10.3390/ijerph19159457>

Reece, R., Bray, I., Sinnett, D., Hayward, R., & Martin, F. (2021). Exposure to green space and prevention of anxiety and depression among young people in urban settings: A global scoping review. *Journal of Public Mental Health*, 20(2), 94–104.

<https://doi.org/10.1108/JPMH-02-2021-0030>

Reece, R., Elliott, L., Bray, I., & Bornioli, A. (2024). How properties of urban greenspaces shape well-being across age groups: A qualitative study. *Wellbeing, Space and Society*, 7, 100206. <https://doi.org/10.1016/j.wss.2024.100206>

Reyes-Riveros, R., Altamirano, A., De La Barrera, F., Rozas-Vásquez, D., Vieli, L., & Meli, P. (2021). Linking public urban green spaces and human well-being: A systematic review. *Urban Forestry & Urban Greening*, 61, 127105. <https://doi.org/10.1016/j.ufug.2021.127105>

Richardson, M., Passmore, H.-A., Lumber, R., Thomas, R., & Hunt, A. (2021). Moments, not minutes: The nature-wellbeing relationship. *International Journal of Wellbeing*, 11(1), Article 1. <https://doi.org/10.5502/ijw.v11i1.1267>

Rickard, S. C., & White, M. P. (2021). Barefoot walking, nature connectedness and psychological restoration: The importance of stimulating the sense of touch for feeling closer to the natural world. *Landscape Research*, 46(7), 975–991. <https://doi.org/10.1080/01426397.2021.1928034>

Rigolon, A. (2016). A complex landscape of inequity in access to urban parks: A literature review. *Landscape and Urban Planning*, 153, 160–169. <https://doi.org/10.1016/j.landurbplan.2016.05.017>

Rigolon, A., Osei Owusu, R., Becerra, M., Cheng, Y. (Daniel), Christensen, J., Connolly, J. J. T., Corbin, C. N. E., Douglas, J. A., Fernandez, M., Jennings, V., Ito, J., Mullenbach, L. E., Nesbitt, L., Osborne Jelks, N., Walker, R., Viera, S., Romero, F., & Espiricueta, A. (2024). Advancing green space equity via policy change: A scoping review and research agenda. *Environmental Science & Policy*, 157, 103765. <https://doi.org/10.1016/j.envsci.2024.103765>

Rios, R., Aiken, L. S., & Zautra, A. J. (2012). Neighborhood Contexts and the Mediating Role of Neighborhood Social Cohesion on Health and Psychological Distress Among Hispanic and Non-Hispanic Residents. *Annals of Behavioral Medicine*, 43(1), 50–61. <https://doi.org/10.1007/s12160-011-9306-9>

Ritchie, H., & Roser, M. (2018). Urbanization. *Our World in Data*. <https://ourworldindata.org/urbanization>

- Ritchie, J., & Spencer, L. (1994). Qualitative data analysis for applied policy research. In A. Bryman & R. G. Burgess (Eds.), *Analyzing qualitative data* (pp. 173–194). Taylor & Francis. https://doi.org/10.4324/9780203413081_chapter_9
- Riva, G., Waterworth, J. A., Waterworth, E. L., & Mantovani, F. (2011). From intention to action: The role of presence. *New Ideas in Psychology*, 29(1), 24–37. <https://doi.org/10.1016/j.newideapsych.2009.11.002>
- Rivera, E., Timperio, A., Loh, V. H. Y., Deforche, B., & Veitch, J. (2021). Critical factors influencing adolescents' active and social park use: A qualitative study using walk-along interviews. *Urban Forestry & Urban Greening*, 58, 126948. <https://doi.org/10.1016/j.ufug.2020.126948>
- Roberts, A. C., Yeap, Y. W., Seah, H. S., Chan, E., Soh, C.-K., & Christopoulos, G. I. (2019). Assessing the suitability of virtual reality for psychological testing. *Psychological Assessment*, 31(3), 318–328. <https://doi.org/10.1037/pas0000663>
- Robinson, C. (2023). Mainstreaming the alternative format thesis in UK higher education: A systematic narrative review of institutional policies. *Perspectives: Policy and Practice in Higher Education*, 27(4), 140–149. <https://doi.org/10.1080/13603108.2023.2239189>
- Roe, J., Aspinall, P. A., & Ward Thompson, C. (2016). Understanding Relationships between Health, Ethnicity, Place and the Role of Urban Green Space in Deprived Urban Communities. *International Journal of Environmental Research and Public Health*, 13(7), Article 7. <https://doi.org/10.3390/ijerph13070681>
- Roe, J., Barnes, L., Napoli, N. J., & Thibodeaux, J. (2019). The Restorative Health Benefits of a Tactical Urban Intervention: An Urban Waterfront Study. *Frontiers in Built Environment*, 5. <https://doi.org/10.3389/fbuil.2019.00071>
- Roe, J. J., Aspinall, P. A., Mavros, P., & Coyne, R. (2013). Engaging the brain: The impact of natural versus urban scenes using novel EEG methods in an experimental setting. *Environmental Sciences*, 1, 93–104. <https://doi.org/10.12988/es.2013.3109>
- Roe, J., & McCay, L. (2021). *Restorative cities: Urban design for mental health and wellbeing*. Bloomsbury. <https://www.tandfonline.com/doi/full/10.1080/23748834.2021.2009706>
- Rogerson, M., Wood, C., Pretty, J., Schoenmakers, P., Bloomfield, D., & Barton, J. (2020). Regular Doses of Nature: The Efficacy of Green Exercise Interventions for Mental Wellbeing.

International Journal of Environmental Research and Public Health, 17(5), 1526.

<https://doi.org/10.3390/ijerph17051526>

Rosa, C. D., Profice, C. C., & Collado, S. (2018). Nature Experiences and Adults' Self-Reported Pro-environmental Behaviors: The Role of Connectedness to Nature and Childhood Nature Experiences. *Frontiers in Psychology*, 9. <https://doi.org/10.3389/fpsyg.2018.01055>

Russell, D., Peplau, L. A., & Cutrona, C. E. (1980). The revised UCLA Loneliness Scale: Concurrent and discriminant validity evidence. *Journal of Personality and Social Psychology*, 39(3), 472–480. <https://doi.org/10.1037//0022-3514.39.3.472>

Ryan, R. M., & Deci, E. L. (2001). On Happiness and Human Potentials: A Review of Research on Hedonic and Eudaimonic Well-Being. *Annual Review of Psychology*, 52(Volume 52, 2001), 141–166. <https://doi.org/10.1146/annurev.psych.52.1.141>

Rydin, Y. (2012). Shaping cities for health: Complexity and the planning of urban environments in the 21st century—The Lancet.

[https://www.thelancet.com/journals/lancet/article/PIIS0140-6736\(12\)60435-8/fulltext](https://www.thelancet.com/journals/lancet/article/PIIS0140-6736(12)60435-8/fulltext)

Rydin, Y., Bleahu, A., Davies, M., Dávila, J. D., Friel, S., Grandis, G. D., Groce, N., Hallal, P. C., Hamilton, I., Howden-Chapman, P., Lai, K.-M., Lim, C. J., Martins, J., Osrin, D., Ridley, I., Scott, I., Taylor, M., Wilkinson, P., & Wilson, J. (2012). Shaping cities for health: Complexity and the planning of urban environments in the 21st century. *The Lancet*, 379(9831), 2079–2108.

[https://doi.org/10.1016/S0140-6736\(12\)60435-8](https://doi.org/10.1016/S0140-6736(12)60435-8)

Sadick, A.-M., & Kamardeen, I. (2020). Enhancing employees' performance and well-being with nature exposure embedded office workplace design. *Journal of Building Engineering*, 32, 101789. <https://doi.org/10.1016/j.jobbe.2020.101789>

Saidatul, A., Paulraj, M. P., Yaacob, S., & Yusnita, M. A. (2011). Analysis of EEG signals during relaxation and mental stress condition using AR modeling techniques. 2011 IEEE International Conference on Control System, Computing and Engineering, 477–481.

<https://doi.org/10.1109/ICCSCE.2011.6190573>

Sarkar, C., & Webster, C. (2017). Urban environments and human health: Current trends and future directions. *Current Opinion in Environmental Sustainability*, 25, 33–44.

<https://doi.org/10.1016/j.cosust.2017.06.001>

Satherley, R.-M., Hazell, C. M., Jones, C. J., & Hanna, P. (2022). A Systematic Review of the Effects of Urban Living on Suicidality and Self-Harm in the UK and Ireland. *Journal of Urban*

Health, 99(3), 385–408. <https://doi.org/10.1007/s11524-022-00611-z>

Schipperijn, J., Ekholm, O., Stigsdotter, U. K., Toftager, M., Bentsen, P., Kamper-Jørgensen, F., & Randrup, T. B. (2010). Factors influencing the use of green space: Results from a Danish national representative survey. *Landscape and Urban Planning*, 95(3), 130–137. <https://doi.org/10.1016/j.landurbplan.2009.12.010>

Schmid, J., Imbach, L., Klaperski, S., & Sudeck, G. (2021). The Natural Environment of Physical Activity and Perceived Stress: The Mediating Role of Specific Recovery Experiences. *Frontiers in Sports and Active Living*, 3. <https://doi.org/10.3389/fspor.2021.706467>

Schofield, D., Cunich, M., Shrestha, R., Tanton, R., Veerman, L., Kelly, S., & Passey, M. (2019). Indirect costs of depression and other mental and behavioural disorders for Australia from 2015 to 2030. *BJPsych Open*, 5(3), e40. <https://doi.org/10.1192/bjo.2019.26>

Schüle, S. A., Hilz, L. K., Dreger, S., & Bolte, G. (2019). Social Inequalities in Environmental Resources of Green and Blue Spaces: A Review of Evidence in the WHO European Region. *International Journal of Environmental Research and Public Health*, 16(7), Article 7. <https://doi.org/10.3390/ijerph16071216>

Scopelliti, M., Carrus, G., & Bonaiuto, M. (2019). Is it Really Nature That Restores People? A Comparison With Historical Sites With High Restorative Potential. *Frontiers in Psychology*, 9. <https://www.frontiersin.org/article/10.3389/fpsyg.2018.02742>

Scott, D., & Jackson, E. L. (1996). Factors that limit and strategies that might encourage people's use of public parks. 14(1), 1–17.

Seaman, P. J., Jones, R., & Ellaway, A. (2010). It's not just about the park, it's about integration too: Why people choose to use or not use urban greenspaces. *International Journal of Behavioral Nutrition and Physical Activity*, 7(1), 78. <https://doi.org/10.1186/1479-5868-7-78>

Seiz, A., Kweon, B.-S., Ellis, C. D., Oh, H., & Pietro, K. (2023). Exploring the Psychophysiological Effects of Viewing Urban Nature through Virtual Reality Using Electroencephalography and Perceived Restorativeness Scale Measures. *Sustainability*, 15(17), Article 17. <https://doi.org/10.3390/su151713090>

Selander, J., Nilsson, M. E., Bluhm, G., Rosenlund, M., Lindqvist, M., Nise, G., & Pershagen, G. (2009). Long-Term Exposure to Road Traffic Noise and Myocardial Infarction. *Epidemiology*, 20(2), 272–279. <https://doi.org/10.1097/EDE.0b013e31819463bd>

- Seligman, M. E. P. (2011). *Flourish: A Visionary New Understanding of Happiness and Wellbeing*. Simon and Schuster.
- Semeraro, T., Scarano, A., Buccolieri, R., Santino, A., & Aarrevaara, E. (2021). Planning of Urban Green Spaces: An Ecological Perspective on Human Benefits. *Land*, 10(2), Article 2. <https://doi.org/10.3390/land10020105>
- Sharma, A., & Singh, M. (2015). Assessing alpha activity in attention and relaxed state: An EEG analysis. 2015 1st International Conference on Next Generation Computing Technologies (NGCT), 508–513. <https://doi.org/10.1109/NGCT.2015.7375171>
- Sharp, L., Donnelly, D., Hegarty, A., Carsin, A.-E., Deady, S., McCluskey, N., Gavin, A., & Comber, H. (2014). Risk of Several Cancers is Higher in Urban Areas after Adjusting for Socioeconomic Status. Results from a Two-Country Population-Based Study of 18 Common Cancers. *Journal of Urban Health : Bulletin of the New York Academy of Medicine*, 91(3), 510–525. <https://doi.org/10.1007/s11524-013-9846-3>
- Silva, M., Loureiro, A., & Cardoso, G. (2016). Social determinants of mental health: A review of the evidence. *The European Journal of Psychiatry*, 30(4), 259–292.
- Sim, J., & Miller, P. (2019). Understanding an Urban Park through Big Data. *International Journal of Environmental Research and Public Health*, 16(20), Article 20. <https://doi.org/10.3390/ijerph16203816>
- Šimundić, A.-M. (2013). Bias in research. *Biochemia Medica*, 23(1), 12–15. <https://doi.org/10.11613/BM.2013.003>
- Singh, D., Kumari, N., & Sharma, P. (2018). A Review of Adverse Effects of Road Traffic Noise on Human Health. *Fluctuation and Noise Letters*, 17(01), 1830001. <https://doi.org/10.1142/S021947751830001X>
- Singh, V., Kumar, A., & Gupta, S. (2022). Mental Health Prevention and Promotion—A Narrative Review. *Frontiers in Psychiatry*, 13, 898009. <https://doi.org/10.3389/fpsy.2022.898009>
- Sjölander, A., Jakobsson Ung, E., Theorell, T., Nilsson, Å., & Ung, K.-A. (2019). Hospital Design with Nature Films Reduces Stress-Related Variables in Patients Undergoing Colonoscopy. *HERD: Health Environments Research & Design Journal*, 12(4), 186–196. <https://doi.org/10.1177/1937586719837754>

Skar, M., Wold, L. C., Gundersen, V., & O'Brien, L. (2016). Why do children not play in nearby nature? Results from a Norwegian survey. *Journal of Adventure Education and Outdoor Learning*, 16(3), 239–255. <https://doi.org/10.1080/14729679.2016.1140587>

Smalley, A. J., & White, M. P. (2023). Beyond blue-sky thinking: Diurnal patterns and ephemeral meteorological phenomena impact appraisals of beauty, awe, and value in urban and natural landscapes. *Journal of Environmental Psychology*, 86, 101955. <https://doi.org/10.1016/j.jenvp.2023.101955>

Smalley, A. J., White, M. P., Sandiford, R., Desai, N., Watson, C., Smalley, N., Tuppen, J., Sakka, L., & Fleming, L. E. (2023). Soundscapes, music, and memories: Exploring the factors that influence emotional responses to virtual nature content. *Journal of Environmental Psychology*, 89, 102060. <https://doi.org/10.1016/j.jenvp.2023.102060>

Snell, T. L., McLean, L. A., McAsey, F., Zhang, M., & Maggs, D. (2019). Nature Streaming: Contrasting the Effectiveness of Perceived Live and Recorded Videos of Nature for Restoration. *Environment and Behavior*, 51(9–10), 1082–1105. <https://doi.org/10.1177/0013916518787318>

Sobngwi, E., Mbanya, J.-C., Unwin, N. C., Porcher, R., Kengne, A.-P., Fezeu, L., Minkoulou, E. M., Tournoux, C., Gautier, J.-F., Aspray, T. J., & Alberti, K. (2004). Exposure over the life course to an urban environment and its relation with obesity, diabetes, and hypertension in rural and urban Cameroon. *International Journal of Epidemiology*, 33(4), 769–776. <https://doi.org/10.1093/ije/dyh044>

Söderlund, J., & Newman, P. (2017). Improving Mental Health in Prisons Through Biophilic Design. *The Prison Journal*, 97(6), 750–772. <https://doi.org/10.1177/0032885517734516>

Soga, M., & Gaston, K. J. (2016). Extinction of experience: The loss of human–nature interactions. *Frontiers in Ecology and the Environment*, 14(2), 94–101. <https://doi.org/10.1002/fee.1225>

Song, C., Ikei, H., Park, B.-J., Lee, J., Kagawa, T., & Miyazaki, Y. (2020). Association between the Psychological Effects of Viewing Forest Landscapes and Trait Anxiety Level. *International Journal of Environmental Research and Public Health*, 17(15), Article 15. <https://doi.org/10.3390/ijerph17155479>

- Song, I., Baek, K., Kim, C., & Song, C. (2023). Effects of nature sounds on the attention and physiological and psychological relaxation. *Urban Forestry & Urban Greening*, 86, 127987. <https://doi.org/10.1016/j.ufug.2023.127987>
- Song, R., Chen, Q., Zhang, Y., Jia, Q., He, H., Gao, T., & Qiu, L. (2022). Psychophysiological restorative potential in cancer patients by virtual reality (VR)-based perception of natural environment. *Frontiers in Psychology*, 13. <https://doi.org/10.3389/fpsyg.2022.1003497>
- Song, X., Lv, X., Yu, D., & Wu, Q. (2018). Spatial-temporal change analysis of plant soundscapes and their design methods. *Urban Forestry & Urban Greening*, 29, 96–105. <https://doi.org/10.1016/j.ufug.2017.11.002>
- Spano, G., Theodorou, A., Reese, G., Carrus, G., Sanesi, G., & Panno, A. (2023). Virtual nature, psychological and psychophysiological outcomes: A systematic review. *Journal of Environmental Psychology*, 89, 102044. <https://doi.org/10.1016/j.jenvp.2023.102044>
- Staats, H. (2012). Restorative environments. In *The Oxford Handbook of Environmental and Conservation Psychology*. OUP USA.
- Staats, H., & Hartig, T. (2004). Alone or with a friend: A social context for psychological restoration and environmental preferences. *Journal of Environmental Psychology*, 24(2), 199–211. <https://doi.org/10.1016/j.jenvp.2003.12.005>
- Stange, K. C., Crabtree, B. F., & Miller, W. L. (2006). Publishing Multimethod Research. *The Annals of Family Medicine*, 4(4), 292–294. <https://doi.org/10.1370/afm.615>
- Stanney, K. M., Hale, K. S., Nahmens, I., & Kennedy, R. S. (2003). What to Expect from Immersive Virtual Environment Exposure: Influences of Gender, Body Mass Index, and Past Experience. *Human Factors*, 45(3), 504–520. <https://doi.org/10.1518/hfes.45.3.504.27254>
- Stevenson, M. P., Schilhab, T., & Bentsen, P. (2018). Attention Restoration Theory II: A systematic review to clarify attention processes affected by exposure to natural environments. *Journal of Toxicology and Environmental Health, Part B*, 21(4), 227–268. <https://doi.org/10.1080/10937404.2018.1505571>
- Stigsdotter, U. K., Ekholm, O., Schipperijn, J., Toftager, M., Kamper-Jørgensen, F., & Randrup, T. B. (2010). Health promoting outdoor environments—Associations between green space, and health, health-related quality of life and stress based on a Danish national representative survey. *Scandinavian Journal of Public Health*, 38(4), 411–417. <https://doi.org/10.1177/1403494810367468>

Stock, S., Bu, F., Fancourt, D., & Mak, H. W. (2022). Longitudinal associations between going outdoors and mental health and wellbeing during a COVID-19 lockdown in the UK. *Scientific Reports*, 12(1), 10580. <https://doi.org/10.1038/s41598-022-15004-0>

Stokols, D. (1972). On the distinction between density and crowding: Some implications for future research. *Psychological Review*, 79(3), 275–277. <https://doi.org/10.1037/h0032706>

Stoltz, J., & Grahn, P. (2021). Perceived sensory dimensions: An evidence-based approach to greenspace aesthetics. *Urban Forestry & Urban Greening*, 59, 126989. <https://doi.org/10.1016/j.ufug.2021.126989>

Subiza-Pérez, M., Pasanen, T., Ratcliffe, E., Lee, K., Bornioli, A., de Bloom, J., & Korpela, K. (2021). Exploring psychological restoration in favorite indoor and outdoor urban places using a top-down perspective. *Journal of Environmental Psychology*, 78, 101706. <https://doi.org/10.1016/j.jenvp.2021.101706>

Subiza-Pérez, M., Vozmediano, L., & San Juan, C. (2017). Restoration in urban settings: Pilot adaptation and psychometric properties of two psychological restoration and place bonding scales / Restauración en contextos urbanos: adaptación piloto y propiedades psicométricas de dos escalas de restauración psicológica y vinculación con el espacio. *PsyEcology*, 8(2), 234–255. <https://doi.org/10.1080/21711976.2017.1311073>

Subiza-Pérez, M., Vozmediano, L., & San Juan, C. (2020). Welcome to your plaza: Assessing the restorative potential of urban squares through survey and objective evaluation methods. *Cities*, 100, 102461. <https://doi.org/10.1016/j.cities.2019.102461>

Sudimac, S., Sale, V., & Kühn, S. (2022). How nature nurtures: Amygdala activity decreases as the result of a one-hour walk in nature. *Molecular Psychiatry*, 27(11), 4446–4452. <https://doi.org/10.1038/s41380-022-01720-6>

Sugiyama, T., & Ward Thompson, C. (2005). Environmental support for outdoor activities and older people's quality of life. *Journal of Housing for the Elderly*, 19(3–4), 167–185. https://doi.org/10.1300/J081v19n03_09

Sun, Y., Li, F., He, T., Meng, Y., Yin, J., Yim, I. S., Xu, L., & Wu, J. (2023). Physiological and affective responses to green space virtual reality among pregnant women. *Environmental Research*, 216, 114499. <https://doi.org/10.1016/j.envres.2022.114499>

Sundevall, E. P., & Jansson, M. (2020). Inclusive Parks across Ages: Multifunction and Urban Open Space Management for Children, Adolescents, and the Elderly. *International Journal*

of Environmental Research and Public Health, 17(24), Article 24.

<https://doi.org/10.3390/ijerph17249357>

Sundquist, K., Frank, G., & Sundquist, J. (2004). Urbanisation and incidence of psychosis and depression: Follow-up study of 4.4 million women and men in Sweden. *The British Journal of Psychiatry*, 184(4), 293–298. <https://doi.org/10.1192/bjp.184.4.293>

Suppakittpaisarn, P., Jiang, X., & Sullivan, W. C. (2017). Green Infrastructure, Green Stormwater Infrastructure, and Human Health: A Review. *Current Landscape Ecology Reports*, 2(4), 96–110. <https://doi.org/10.1007/s40823-017-0028-y>

Swami, V. (2024). Associations between nature exposure and body image: A critical, narrative review of the evidence. *Acta Psychologica*, 248, 104355.

<https://doi.org/10.1016/j.actpsy.2024.104355>

Swami, V., White, M. P., Voracek, M., Tran, U. S., Aavik, T., Ranjbar, H. A., Adebayo, S. O., Afhami, R., Ahmed, O., Aimé, A., Akel, M., Al Halbusi, H., Alexias, G., Ali, K. F., Alp-Dal, N., Alsahani, A. B., Álvarez-Solas, S., Soares Amaral, A. C., Andrianto, S., ... Stieger, S. (2024). Exposure and connectedness to natural environments: An examination of the measurement invariance of the Nature Exposure Scale (NES) and Connectedness to Nature Scale (CNS) across 65 nations, 40 languages, gender identities, and age groups. *Journal of Environmental Psychology*, 99, 102432. <https://doi.org/10.1016/j.jenvp.2024.102432>

Swierad, E. M., & Huang, T. T. K. (2018). An Exploration of Psychosocial Pathways of Parks' Effects on Health: A Qualitative Study. *International Journal of Environmental Research and Public Health*, 15(8), Article 8. <https://doi.org/10.3390/ijerph15081693>

Taherdoost, H. (2022). What are Different Research Approaches? Comprehensive Review of Qualitative, Quantitative, and Mixed Method Research, Their Applications, Types, and Limitations (SSRN Scholarly Paper 4178694). <https://papers.ssrn.com/abstract=4178694>

Tariq, T., Zahid, N., & Eisawi, W. (2024). Evaluating the Psychological Benefits of Urban Green Spaces: A Longitudinal Experimental Study. *Insights-Journal of Life and Social Sciences*, 2(1), Article 1.

Taylor, L., & Hochuli, D. (2015). Creating better cities: How biodiversity and ecosystem functioning enhance urban residents' wellbeing. *Urban Ecosystems*, 18, 1–16.

<https://doi.org/10.1007/s11252-014-0427-3>

- Taylor, L., & Hochuli, D. F. (2017). Defining greenspace: Multiple uses across multiple disciplines. *Landscape and Urban Planning*, 158, 25–38.
<https://doi.org/10.1016/j.landurbplan.2016.09.024>
- Tennant, R., Hiller, L., Fishwick, R., Platt, S., Joseph, S., Weich, S., Parkinson, J., Secker, J., & Stewart-Brown, S. (2007). The Warwick-Edinburgh Mental Well-being Scale (WEMWBS): Development and UK validation. *Health and Quality of Life Outcomes*, 5(1), 63.
<https://doi.org/10.1186/1477-7525-5-63>
- Thang, L., & Kaplan, M. (2012). *Environmental Gerontology: Making Meaningful Places in Old Age*. In *Intergenerational Pathways for Building Relational Spaces and Places*. Springer Publishing Company.
- Thomson, R. M., & Katikireddi, S. V. (2018). Mental health and the jilted generation: Using age-period-cohort analysis to assess differential trends in young people’s mental health following the Great Recession and austerity in England. *Social Science & Medicine*, 214, 133–143. <https://doi.org/10.1016/j.socscimed.2018.08.034>
- Tilley, S., Neale, C., Patuano, A., & Cinderby, S. (2017). Older People’s Experiences of Mobility and Mood in an Urban Environment: A Mixed Methods Approach Using Electroencephalography (EEG) and Interviews. *International Journal of Environmental Research and Public Health*, 14(2), 151. <https://doi.org/10.3390/ijerph14020151>
- Tillmann, S., Tobin, D., Avison, W., & Gilliland, J. (2018). Mental health benefits of interactions with nature in children and teenagers: A systematic review. 958–966.
- Trammell, J. P., Harriger, J. A., & Krumrei-Mancuso, E. J. (2024). Walking in nature may improve affect but not cognition. *Frontiers in Psychology*, 14.
<https://doi.org/10.3389/fpsyg.2023.1258378>
- Tran, Y., Austin, P., Lo, C., Craig, A., Middleton, J. W., Wrigley, P. J., & Siddall, P. (2022). An Exploratory EEG Analysis on the Effects of Virtual Reality in People with Neuropathic Pain Following Spinal Cord Injury. *Sensors*, 22(7), Article 7. <https://doi.org/10.3390/s22072629>
- Triguero-Mas, M., Donaire-Gonzalez, D., Seto, E., Valentín, A., Martínez, D., Smith, G., Hurst, G., Carrasco-Turigas, G., Masterson, D., van den Berg, M., Ambròs, A., Martínez-Íñiguez, T., Dedele, A., Ellis, N., Grazulevicius, T., Voorsmit, M., Cirach, M., Cirac-Claveras, J., Swart, W., ... Nieuwenhuijsen, M. J. (2017). Natural outdoor environments and mental health: Stress as

a possible mechanism. *Environmental Research*, 159, 629–638.

<https://doi.org/10.1016/j.envres.2017.08.048>

Tsunetsugu, Y., Lee, J., Park, B.-J., Tyrväinen, L., Kagawa, T., & Miyazaki, Y. (2013).

Physiological and psychological effects of viewing urban forest landscapes assessed by multiple measurements. *Landscape and Urban Planning*, 113, 90–93.

<https://doi.org/10.1016/j.landurbplan.2013.01.014>

Tyrväinen, L., Ojala, A., Korpela, K., Lanki, T., Tsunetsugu, Y., & Kagawa, T. (2014). The influence of urban green environments on stress relief measures: A field experiment.

Journal of Environmental Psychology, 38, 1–9. <https://doi.org/10.1016/j.jenvp.2013.12.005>

Tzoulas, K., Korpela, K., Venn, S., Yli-Pelkonen, V., Kaźmierczak, A., Niemela, J., & James, P.

(2007). Promoting ecosystem and human health in urban areas using Green Infrastructure: A literature review. *Landscape and Urban Planning*, 81(3), 167–178.

<https://doi.org/10.1016/j.landurbplan.2007.02.001>

Uebel, K., Marselle, M., Dean, A. J., Rhodes, J. R., & Bonn, A. (2021). Urban green space soundscapes and their perceived restorativeness. *People and Nature*, 3(3), 756–769.

<https://doi.org/10.1002/pan3.10215>

Ulrich, R. S. (1981). Natural Versus Urban Scenes: Some Psychophysiological Effects.

Environment and Behavior, 13(5), 523–556. <https://doi.org/10.1177/0013916581135001>

Ulrich, R. S. (1983). Aesthetic and Affective Response to Natural Environment. In I. Altman & J. F. Wohlwill (Eds.), *Behavior and the Natural Environment* (pp. 85–125). Springer US.

https://doi.org/10.1007/978-1-4613-3539-9_4

Ulrich, R. S. (1984). View Through a Window May Influence Recovery from Surgery. *Science*, 224(4647), 420–421. <https://doi.org/10.1126/science.6143402>

Ulrich, R. S., Simons, R. F., Losito, B. D., Fiorito, E., Miles, M. A., & Zelson, M. (1991). Stress recovery during exposure to natural and urban environments. *Journal of Environmental Psychology*, 11(3), 201–230. [https://doi.org/10.1016/S0272-4944\(05\)80184-7](https://doi.org/10.1016/S0272-4944(05)80184-7)

Ünal, A. B., Pals, R., Steg, L., Siero, F. W., & van der Zee, K. I. (2022). Is virtual reality a valid tool for restorative environments research? *Urban Forestry & Urban Greening*, 74, 127673.

<https://doi.org/10.1016/j.ufug.2022.127673>

United Nations. (2018). 68% of the world population projected to live in urban areas by 2050, says UN. United Nations; United Nations. <https://www.un.org/uk/desa/68-worldpopulation-projected-live-urban-areas-2050-says-un>

United Nations Department of Economic and Social Affairs. (2012). World Economic Situation and Prospects 2022 | Department of Economic and Social Affairs. <https://www.un.org/development/desa/dpad/publication/world-economic-situation-andprospects-2022/>

United Nations Department of Economic and Social Affairs. (2013). World Population Ageing 2013. <https://www.un.org/en/development/desa/population/publications/pdf/ageing/WorldPopulationAgeing2013.pdf>

Unity Technologies. (2024). Unity Real-Time Development Platform | 3D, 2D, VR & AR Engine [Computer software]. Unity Technologies. <https://unity.com>

Vacher, P., Filaire, E., Mourot, L., & Nicolas, M. (2019). Stress and recovery in sports: Effects on heart rate variability, cortisol, and subjective experience. *International Journal of Psychophysiology*, 143, 25–35. <https://doi.org/10.1016/j.ijpsycho.2019.06.011> van den Berg, A. E. (2017). From Green Space to Green Prescriptions: Challenges and Opportunities for Research and Practice. *Frontiers in Psychology*, 8. <https://www.frontiersin.org/articles/10.3389/fpsyg.2017.00268>

van den Berg, A. E., Jorgensen, A., & Wilson, E. R. (2014). Evaluating restoration in urban green spaces: Does setting type make a difference? *Landscape and Urban Planning*, 127, 173–181. <https://doi.org/10.1016/j.landurbplan.2014.04.012> van den Berg, A. E., Joye, Y., & Koole, S. L. (2016). Why viewing nature is more fascinating and restorative than viewing buildings: A closer look at perceived complexity. *Urban Forestry & Urban Greening*, 20, 397–401. <https://doi.org/10.1016/j.ufug.2016.10.011>

van den Berg, A. E., Koole, S. L., & van der Wulp, N. Y. (2003). Environmental preference and restoration: (How) are they related? *Journal of Environmental Psychology*, 23(2), 135–146. [https://doi.org/10.1016/S0272-4944\(02\)00111-1](https://doi.org/10.1016/S0272-4944(02)00111-1)

van den Berg, M. M., van Poppel, M., van Kamp, I., Ruijsbroek, A., Triguero-Mas, M., Gidlow, C., Nieuwenhuijsen, M. J., Gražulevičienė, R., van Mechelen, W., Kruize, H., & Maas, J.

(2019). Do Physical Activity, Social Cohesion, and Loneliness Mediate the Association Between Time Spent Visiting Green Space and Mental Health? *Environment and Behavior*, 51(2), 144–166. <https://doi.org/10.1177/0013916517738563>

van den Berg, M., Wendel-Vos, W., van Poppel, M., Kemper, H., van Mechelen, W., & Maas, J. (2015). Health benefits of green spaces in the living environment: A systematic review of epidemiological studies. *Urban Forestry & Urban Greening*, 14(4), 806–816. <https://doi.org/10.1016/j.ufug.2015.07.008>

van Gelder, J.-L., Otte, M., & Luciano, E. C. (2014). Using virtual reality in criminological research. *Crime Science*, 3(1), 10. <https://doi.org/10.1186/s40163-014-0010-5>

van Hecke, L., Deforche, B., Dyck, D. V., Bourdeaudhuij, I. D., Veitch, J., & Cauwenberg, J. V. (2016). Social and Physical Environmental Factors Influencing Adolescents' Physical Activity in Urban Public Open Spaces: A Qualitative Study Using Walk-Along Interviews. *PLOS ONE*, 11(5), e0155686. <https://doi.org/10.1371/journal.pone.0155686>

van Houwelingen-Snippe, J., Allouch, S. B., & Van Rompay, T. J. L. (2021). Virtual Reality Representations of Nature to Improve Well-Being amongst Older Adults: A Rapid Review. *Journal of Technology in Behavioral Science*, 6(3), 464–485. <https://doi.org/10.1007/s41347-021-00195-6>

van Houwelingen-Snippe, J., Allouch, S. B., & van Rompay, T. J. L. (2023a). Designing digital nature for older adults: A mixed method approach. *Digital Health*, 9, 20552076231218504. <https://doi.org/10.1177/20552076231218504>

van Houwelingen-Snippe, J. van, Allouch, S. B., & van Rompay, T. J. L. (2023b). 'That is a place where I would want to go': Investigating digital nature to enhance social wellbeing among older adults. *Ageing & Society*, 43(11), 2605–2628. <https://doi.org/10.1017/S0144686X2100177X>

Vanaken, G.-J., & Danckaerts, M. (2018). Impact of Green Space Exposure on Children's and Adolescents' Mental Health: A Systematic Review. *International Journal of Environmental Research and Public Health*, 15(12), 2668. <https://doi.org/10.3390/ijerph15122668>

- Vassiljev, P., Bell, S., Balicka, J., & Amrita, U. A. A. (2020). Urban Blue Acupuncture: An Experiment on Preferences for Design Options Using Virtual Models. *Sustainability*, 12(24), Article 24. <https://doi.org/10.3390/su122410656>
- Veisten, K., Smyrnova, Y., Klæboe, R., Hornikx, M., Mosslemi, M., & Kang, J. (2012). Valuation of green walls and green roofs as soundscape measures: Including monetised amenity values together with noise-attenuation values in a cost-benefit analysis of a green wall affecting courtyards. *International Journal of Environmental Research and Public Health*, 9(11). <https://doi.org/10.3390/ijerph9113770>
- Veitch, J., Ball, K., Rivera, E., Loh, V., Deforche, B., Best, K., & Timperio, A. (2021). What entices older adults to parks? Identification of park features that encourage park visitation, physical activity, and social interaction. *Landscape and Urban Planning*, 217, 104254. <https://doi.org/10.1016/j.landurbplan.2021.104254>
- Veitch, J., Flowers, E., Ball, K., Deforche, B., & Timperio, A. (2020a). Designing parks for older adults: A qualitative study using walk-along interviews. *Urban Forestry & Urban Greening*, 54, 126768. <https://doi.org/10.1016/j.ufug.2020.126768>
- Veitch, J., Flowers, E., Ball, K., Deforche, B., & Timperio, A. (2020b). Exploring Children's Views on Important Park Features: A Qualitative Study Using Walk-Along Interviews. *International Journal of Environmental Research and Public Health*, 17(13), 4625. <https://doi.org/10.3390/ijerph17134625>
- Velarde, M. D., Fry, G., & Tveit, M. (2007). Health effects of viewing landscapes – Landscape types in environmental psychology. *Urban Forestry & Urban Greening*, 6(4), 199–212. <https://doi.org/10.1016/j.ufug.2007.07.001>
- Ventriglio, A., Torales, J., Castaldelli-Maia, J. M., Berardis, D. D., & Bhugra, D. (2021). Urbanization and emerging mental health issues. *CNS Spectrums*, 26(1), 43–50. <https://doi.org/10.1017/S1092852920001236>
- Viollon, S., Lavandier, C., & Drake, C. (2002). Influence of visual setting on sound ratings in an urban environment. *Applied Acoustics*, 63(5), 493–511. [https://doi.org/10.1016/S0003-682X\(01\)00053-6](https://doi.org/10.1016/S0003-682X(01)00053-6)
- Völker, S., & Kistemann, T. (2011). The impact of blue space on human health and well-being

– Salutogenetic health effects of inland surface waters: A review. *International Journal of Hygiene and Environmental Health*, 214(6), 449–460.

<https://doi.org/10.1016/j.ijheh.2011.05.001>

Voogt, J. A., & Oke, T. R. (2003). Thermal remote sensing of urban climates. *Remote Sensing of Environment*, 86(3), 370–384. [https://doi.org/10.1016/S0034-4257\(03\)00079-8](https://doi.org/10.1016/S0034-4257(03)00079-8)

Wan, C., Shen, G. Q., & Choi, S. (2021). Underlying relationships between public urban green spaces and social cohesion: A systematic literature review. *City, Culture and Society*, 24, 100383. <https://doi.org/10.1016/j.ccs.2021.100383>

Wang, R., Zhao, J., Meitner, M. J., Hu, Y., & Xu, X. (2019). Characteristics of urban green spaces in relation to aesthetic preference and stress recovery. *Urban Forestry & Urban Greening*, 41, 6–13. <https://doi.org/10.1016/j.ufug.2019.03.005>

Wang, T.-C., Sit, C. H.-P., Tang, T.-W., & Tsai, C.-L. (2020). Psychological and Physiological Responses in Patients with Generalized Anxiety Disorder: The Use of Acute Exercise and Virtual Reality Environment. *International Journal of Environmental Research and Public Health*, 17(13), 4855. <https://doi.org/10.3390/ijerph17134855>

Wang, X., Rodiek, S., Wu, C., Chen, Y., & Li, Y. (2016). Stress recovery and restorative effects of viewing different urban park scenes in Shanghai, China. *Urban Forestry & Urban Greening*, 15, 112–122. <https://doi.org/10.1016/j.ufug.2015.12.003>

Wang, X., Shi, Y., Zhang, B., & Chiang, Y. (2019). The Influence of Forest Resting Environments on Stress Using Virtual Reality. *International Journal of Environmental Research and Public Health*, 16(18), 3263. <https://doi.org/10.3390/ijerph16183263>

Wang, Z., Zhu, Z., Xu, M., & Qureshi, S. (2021). Fine-grained assessment of greenspace satisfaction at regional scale using content analysis of social media and machine learning.

Science of The Total Environment, 776, 145908.

<https://doi.org/10.1016/j.scitotenv.2021.145908>

Ward Thompson, C., Roe, J., Aspinall, P., Mitchell, R., Clow, A., & Miller, D. (2012). More green space is linked to less stress in deprived communities: Evidence from salivary cortisol patterns. *Landscape and Urban Planning*, 105(3), 221–229.

<https://doi.org/10.1016/j.landurbplan.2011.12.015>

Weber, A. M., & Trojan, J. (2018). The Restorative Value of the Urban Environment: A

- Systematic Review of the Existing Literature. *Environmental Health Insights*, 12, 1178630218812805. <https://doi.org/10.1177/1178630218812805>
- Weiderpass, E. (2010). Lifestyle and Cancer Risk. *Journal of Preventive Medicine and Public Health*, 43(6), 459. <https://doi.org/10.3961/jpmph.2010.43.6.459>
- Weimann, H., Björk, J., & Håkansson, C. (2019). Experiences of the Urban Green Local Environment as a Factor for Well-Being among Adults: An Exploratory Qualitative Study in Southern Sweden. *International Journal of Environmental Research and Public Health*, 16(14), Article 14. <https://doi.org/10.3390/ijerph16142464>
- Wendelboe-Nelson, C., Kelly, S., Kennedy, M., & Cherrie, J. (2019). A Scoping Review Mapping Research on Green Space and Associated Mental Health Benefits. *International Journal of Environmental Research and Public Health*, 16(12), 2081. <https://doi.org/10.3390/ijerph16122081>
- Weng, X., Liu, Y., Ma, J., Wang, W., Yang, G., & Caballero, B. (2007). An urban–rural comparison of the prevalence of the metabolic syndrome in Eastern China. *Public Health Nutrition*, 10(2), 131–136. <https://doi.org/10.1017/S1368980007226023>
- White, M. P., Elliott, L. R., Gascon, M., Roberts, B., & Fleming, L. E. (2020). Blue space, health and well-being: A narrative overview and synthesis of potential benefits. *Environmental Research*, 191, 110169. <https://doi.org/10.1016/j.envres.2020.110169>
- White, M. P., Yeo, N., Vassiljev, P., Lundstedt, R., Wallergård, M., Albin, M., & Löhmus, M. (2018). A prescription for ‘nature’—The potential of using virtual nature in therapeutics. *Neuropsychiatric Disease and Treatment*, Volume 14, 3001–3013. <https://doi.org/10.2147/NDT.S179038>
- Whitehead, M., & Dahlgren, G. (1991). What can be done about inequalities in health? *The Lancet*, 338(8774), 1059–1063. [https://doi.org/10.1016/0140-6736\(91\)91911-D](https://doi.org/10.1016/0140-6736(91)91911-D)
- Williams, N. (2014a). PHQ-9. *Occupational Medicine*, 64(2), 139–140. <https://doi.org/10.1093/occmed/kqt154>
- Williams, N. (2014b). The GAD-7 questionnaire. *Occupational Medicine*, 64(3), 224. <https://doi.org/10.1093/occmed/kqt161>
- Wilson, E. O. (1984). *Biophilia*. Harvard University Press.

Wood, C., Wicks, C., & Barton, J. (2023). Green spaces for mental disorders. *Current Opinion in Psychiatry*, 36(1), 41–46. <https://doi.org/10.1097/YCO.0000000000000830>

Wood, L., Hooper, P., Foster, S., & Bull, F. (2017). Public green spaces and positive mental health – investigating the relationship between access, quantity and types of parks and mental wellbeing. *Health & Place*, 48, 63–71.
<https://doi.org/10.1016/j.healthplace.2017.09.002>

World Economic Forum. (2018, May 18). Depression is the no. 1 cause of ill health and disability worldwide. World Economic Forum.
<https://www.weforum.org/agenda/2018/05/depression-prevents-many-of-us-from-leading-healthy-and-productive-lives-being-the-no-1-cause-of-ill-health-and-disability-worldwide/>

World Health Organization. (1999). Guidelines for community noise.
<https://www.who.int/publications-detail-redirect/a68672>

World Health Organization. (2005). Promoting mental health: Concepts, emerging evidence, practice; a report. World Health Organization.

World Health Organization. (2010). Hidden Cities: Unmasking and Overcoming Health Inequities in Urban Settings. World Health Organization.

World Health Organization. (2011a). Burden of disease from environmental noise—Quantification of healthy life years lost in Europe. <https://www.who.int/publications-detailredirect/9789289002295>

World Health Organization. (2011b). Global burden of mental disorders and the need for a comprehensive, coordinated response from health and social sectors at the country level. https://apps.who.int/gb/ebwha/pdf_files/EB130/B130_9-en.pdf

World Health Organization. (2013). What is ‘active ageing’?
http://www.who.int/ageing/active_ageing/en/

World Health Organization. (2016). Urban green spaces: A brief for action.
<https://www.who.int/europe/publications/i/item/9789289052498>

World Health Organization. (2020). Healthy cities effective approach to a rapidly changing world. <https://iris.who.int/bitstream/handle/10665/331946/9789240004825-eng.pdf>

World Health Organization. (2021). Comprehensive Mental Health Action Plan 2013-2030. <https://iris.who.int/bitstream/handle/10665/345301/9789240031029-eng.pdf?sequence=1>

World Health Organization. (2022a). Ageing and health. <https://www.who.int/newsroom/fact-sheets/detail/ageing-and-health>

World Health Organization. (2022b). Mental health. <https://www.who.int/news-room/factsheets/detail/mental-health-strengthening-our-response>

World Health Organization. (2022c). Urban health. <https://www.who.int/news-room/factsheets/detail/urban-health>

World Health Organization. (2023a). Assessing the value of urban green and blue spaces for health and well-being (WHO/EURO:2023-7508-47275-69347). World Health Organization. Regional Office for Europe. <https://apps.who.int/iris/handle/10665/367630>

World Health Organization. (2023b). Depressive disorder (depression). <https://www.who.int/news-room/fact-sheets/detail/depression>

World Health Organization. (2023c). Mental health. <https://www.who.int/healthtopics/mental-health>

World Health Organization. (2023d). Mental health of older adults. <https://www.who.int/news-room/fact-sheets/detail/mental-health-of-older-adults>

World Health Organization. (2024a). Achieving well-being: A global framework for integrating well-being into public health utilizing a health promotion approach. World Health Organization.

World Health Organization. (2024b). Adolescent and young adult health. <https://www.who.int/news-room/fact-sheets/detail/adolescents-health-risks-and-solutions>

World Health Organization. (2024c). Mental health. Mental Health. <https://www.who.int/health-topics/mental-health>

World Health Organization. (2024d). Promoting mental health. <https://www.who.int/westernpacific/activities/promoting-mental-health>

Xu, J., Liu, N., Polemiti, E., Garcia-Mondragon, L., Tang, J., Liu, X., Lett, T., Yu, L., Nöthen, M. M., Feng, J., Yu, C., Marquand, A., & Schumann, G. (2023). Effects of urban living environments on mental health in adults. *Nature Medicine*, 29(6), 1456–1467. <https://doi.org/10.1038/s41591-023-02365-w>

- Xu, Z., Gao, X., Wang, Z., & Fan, J. (2019). Big Data-Based Evaluation of Urban Parks: A Chinese Case Study. *Sustainability*, 11(7), Article 7. <https://doi.org/10.3390/su11072125>
- Yang, F., Bao, Z. Y., & Zhu, Z. J. (2011). An Assessment of Psychological Noise Reduction by Landscape Plants. *International Journal of Environmental Research and Public Health*, 8(4), Article 4. <https://doi.org/10.3390/ijerph8041032>
- Yao, W., Zhang, X., & Gong, Q. (2021). The effect of exposure to the natural environment on stress reduction: A meta-analysis. *Urban Forestry & Urban Greening*, 57, 126932. <https://doi.org/10.1016/j.ufug.2020.126932>
- Yen, I. H., & Syme, S. L. (1999). The Social Environment and Health: A Discussion of the Epidemiologic Literature. *Annual Review of Public Health*, 20(1), 287–308. <https://doi.org/10.1146/annurev.publhealth.20.1.287>
- Yeo, N. L., White, M. P., Alcock, I., Garside, R., Dean, S. G., Smalley, A. J., & Gatersleben, B. (2020). What is the best way of delivering virtual nature for improving mood? An experimental comparison of high definition TV, 360° video, and computer generated virtual reality. *Journal of Environmental Psychology*, 72, 101500. <https://doi.org/10.1016/j.jenvp.2020.101500>
- Yetton, B.D., Revord, J., Margolis, S., Lyubomirsky, S., & Seitz, A.R. (2019). Cognitive and Physiological Measures in Well-Being Science: Limitations and Lessons. *Frontiers in Psychology*, 12(1), 1630.
- Yin, J., Bratman, G. N., Browning, M. H. E. M., Spengler, J. D., & Olvera-Alvarez, H. A. (2022). Stress recovery from virtual exposure to a brown (desert) environment versus a green environment. *Journal of Environmental Psychology*, 81, 101775. <https://doi.org/10.1016/j.jenvp.2022.101775>
- Yin, J., Yuan, J., Arfaei, N., Catalano, P. J., Allen, J. G., & Spengler, J. D. (2020). Effects of biophilic indoor environment on stress and anxiety recovery: A between-subjects experiment in virtual reality. *Environment International*, 136, 105427. <https://doi.org/10.1016/j.envint.2019.105427>
- Young, S. N. (2008). The neurobiology of human social behaviour: An important but neglected topic. *Journal of Psychiatry & Neuroscience : JPN*, 33(5), 391.

- Yu, C.-P., Lee, H.-Y., & Luo, X.-Y. (2018). The effect of virtual reality forest and urban environments on physiological and psychological responses. *Urban Forestry & Urban Greening*, 35, 106–114. <https://doi.org/10.1016/j.ufug.2018.08.013>
- Zabini, F., Albanese, L., Becheri, F. R., Gavazzi, G., Giganti, F., Giovanelli, F., Gronchi, G., Guazzini, A., Laurino, M., Li, Q., Marzi, T., Mastorci, F., Meneguzzo, F., Righi, S., & Viggiano, M. P. (2020). Comparative Study of the Restorative Effects of Forest and Urban Videos during COVID-19 Lockdown: Intrinsic and Benchmark Values. *International Journal of Environmental Research and Public Health*, 17(21), Article 21. <https://doi.org/10.3390/ijerph17218011>
- Zhang, J., Qi, R., & Zhang, H. (2023). Examining the Impact of Crowding Perception on the Generation of Negative Emotions among Users of Small Urban Micro Public Spaces. *Sustainability*, 15(22), Article 22. <https://doi.org/10.3390/su152216104>
- Zhang, T., Liu, J., & Li, H. (2019). Restorative Effects of Multi-Sensory Perception in Urban Green Space: A Case Study of Urban Park in Guangzhou, China. *International Journal of Environmental Research and Public Health*, 16(24), Article 24. <https://doi.org/10.3390/ijerph16244943>
- Zhang, Y., Mavoa, S., Zhao, J., Raphael, D., & Smith, M. (2020). The Association between Green Space and Adolescents' Mental Well-Being: A Systematic Review. *International Journal of Environmental Research and Public Health*, 17(18), Article 18. <https://doi.org/10.3390/ijerph17186640>
- Zhang, Y., Zhang, L., Hua, H., Jin, J., Zhu, L., Shu, L., Xu, X., Kuang, F., & Liu, Y. (2021). Relaxation Degree Analysis Using Frontal Electroencephalogram Under Virtual Reality Relaxation Scenes. *Frontiers in Neuroscience*, 15, 719869. <https://doi.org/10.3389/fnins.2021.719869>
- Zhao, J., & Huang, Y. (2021). Physical Characteristics of Urban Green Spaces in Relation to Perceived Safety. *Journal of Urban Planning and Development*, 147(4), 05021032. [https://doi.org/10.1061/\(ASCE\)UP.1943-5444.0000742](https://doi.org/10.1061/(ASCE)UP.1943-5444.0000742)
- Zhou, Y., Yang, L., Yu, J., & Guo, S. (2022). Do seasons matter? Exploring the dynamic link between blue-green space and mental restoration. *Urban Forestry & Urban Greening*, 73, 127612. <https://doi.org/10.1016/j.ufug.2022.127612>
- Zhu, X., Gao, M., Zhao, W., & Ge, T. (2020). Does the Presence of Birdsongs Improve

Perceived Levels of Mental Restoration from Park Use? Experiments on Parkways of Harbin Sun Island in China. *International Journal of Environmental Research and Public Health*, 17(7), 2271. <https://doi.org/10.3390/ijerph17072271>

Zuckerman, M. (1977). Development of a situation-specific trait-state test for the prediction and measurement of affective responses. *Journal of Consulting and Clinical Psychology*, 45(4), 513–523. <https://doi.org/10.1037/0022-006X.45.4.513>

Appendix

Appendix 1. Chapter 3 extended methods

Sample size

In regard to sample size, 20 participants were recruited: 5 participants per age group (11-16yrs+, 16-24yrs+, adults 25yrs+, and older adults 65yrs+). The research questions for this study were quite specific and easy to address based on participants discussing their experience visiting UGS (e.g., it was not an awkward or distressing topic)(Morse, 2000), it was expected that participants would talk openly. This would then allow for a deep and detailed response from participants which would allow enough data to reach saturation in a sample size of 20 participants (Hennink & Kaiser, 2022). Whilst often debated, saturation is referred to in qualitative research as being a measure of robustness and validity (O'Reilly & Parker, 2013). The aim of this study was to take an exploratory, in-depth approach, and this was sufficient with a smaller sample size. Hennink & Kaiser (2022) confirm that saturation can be reached with small sample sizes and whilst a definite answer for the correct sample size is illusive, they did report that saturation can be reached with 9-17 interviews. The aim of the study was not to establish a comprehensive set of UGS correlates of well-being among different generations across a large demographic. That type of study aim might be better suited to a quantitative methodology and different research question.

Interview questions

The open ended questions asked to participants were formulated based on the research questions and aims of the study. The semi-structured nature of this study meant that a topic guide was used during the interviews, which included several topics that the study needed to be explored in order to answer the research questions. The topic guide is split into sections for introductory questions, main questions, and closing questions. The introductory questions were included for several reasons. Firstly, they help to build rapport with participants which can help them to feel comfortable and open to talking with myself as the researcher. With participants feeling comfortable in the setting, this can lead to them sharing rich and detail answers to the main questions which come later on (McGrath et al., 2019). This can be challenging due to the limited amount of time with each participant (Dicicco-Bloom & Crabtree, 2006). The introductory questions also were included so that I could make sure again that participants did have experience with visiting UGS and were

eligible for taking part. The questions asked for example, 'do you visit urban greenspaces?' and 'how often do you visit urban greenspaces?'. Due to the wide range of urban greenspaces which participants could talk about (e.g., parks, community gardens, cycle paths etc), this introduction allowed for participants to illustrate the type(s) of spaces that they were going to discuss from there on. The introductory questions set-up the main questions which followed, and finally the closing questions which allowed participants to add anything else they wanted or ask myself as the researcher any questions.

Transcription

All interviews were conducted online using Zoom where the built-in software was used to automatically transcribe the recordings. The participants were made aware at the beginning of the interview that the Zoom call would be recorded and transcribed and I checked to make sure both of these were functioning before proceeding with the interview questions. The automatic transcription was not entirely accurate and required more time go through each transcript and correct the mistakes. The automatic transcription was often inaccurate if participants spoke fast, quietly, or were situated at a distance from their screen. Information which may have made the participants identifiable, or was sensitive, was removed, for example, names and locations when described in relation to their home (e.g., "XXX park down the road from my house"). All transcriptions were saved and stored to OneDrive which only the supervisory team and I had password-protected access to.

Appendix 2. Chapter 3 ethical approval



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UWE REC REF No: HAS.22.04.091

26th May 2022

Rebecca Reece

Dear Rebecca

Application title: Multi-sensory components of urban green environments for intergenerational wellbeing

Thank you for responding to the conditions raised in my letter to you of 18th May 2022 .

I can now confirm full ethics approval for your project, but please note that with the move towards living with COVID in England and across the devolved nations, guidance as set by the UK Government and the relevant devolved administrations has been updated, with much being removed in England by 1 April 2022. If you have any questions about how this may affect starting or continuing your research project or for further information, please contact res.admin@uwe.ac.uk. For research governance guidance, please contact researchgovernance@uwe.ac.uk. Please also refer to [UWE Bristol Coronavirus advice](#).

From Tuesday 1 March, the moratorium on UWE Bristol international travel has been lifted and travellers are now able to request permission to travel through a new online approval process. All applications for international travel must follow the new process with bookings to be made in liaison with the Finance Services team through the University's designated travel management company. Please see the guidance at <https://intranet.uwe.ac.uk/tasks-guides/Guide/travelling-on-university-business>.

The following standard conditions apply to all research given ethical approval by a UWE Research Ethics Committee:

1. You must notify the relevant UWE Research Ethics Committee in advance if you wish to make significant amendments to the original application: these include any changes to the study protocol which have an ethical dimension. Please note that any changes approved by an external research ethics committee must also be communicated to the relevant UWE committee.
2. You must notify the Faculty Research Ethics Committee if you terminate your research before completion.
3. You must notify the Faculty Research Ethics Committee if there are any serious events or developments in the research that have an ethical dimension.

Please ensure that before proceeding with your research:

- you have sought contractual advice from the UWE Contracts Team Amy.Charles@uwe.ac.uk if your research involves external funding and/or contracts with partner organisations;
- You have sought advice from the UWE Data Protection Team (dataprotection@uwe.ac.uk) if, in relation to collecting and/or sharing personal data, a third party (i.e. any person or institution extraneous to UWE) is involved in the research project.

Please note: The Research Ethics Sub-Committee (RESC) is required to monitor and audit the ethical conduct of research involving human participants, data and tissue conducted by academic staff, students and researchers. Your project may be selected for audit from the research projects submitted to and approved by the RESC and its committees.

We wish you well with your research.

Yours sincerely

Dr Julie Woodley

Chair

Faculty Research Ethics Committee

c.c. Chris Alford

Appendix 3. Chapter 3 consent form



Researching which aspects of urban green spaces are important for younger and older people.

You are invited to take part in an interview as part of a research project at the University of the West of England. The purpose of this study is to identify and understand which features of urban green environments (e.g. a park or a community garden), are preferred and valuable to your mental wellbeing.

Please ensure that you have read and understood the information contained in the Participant Information Sheet and asked any questions before you provide consent. If you have any questions please contact a member of the research team, whose details are set out on the Participant Information Sheet.

If you are happy to take part in this interview, please click the next arrow at the bottom of this page. By clicking this, you are providing consent and agree to the following statements:

- I have read and understood the information in the Participant Information Sheet which I have been given to read before asked to sign this form.
- I have been given the opportunity to ask questions about the study.
- I have had my questions answered satisfactorily by the research team.
- I understand that I will be audio-recorded, and the recording will be destroyed once the data has been transcribed for analysis.
- I agree that anonymised quotes may be used in the final report of this study.
- I understand that my participation is voluntary and that I am free to withdraw at any time until the data has been anonymised, without giving a reason.
- I agree to take part in the research.



Participant Information Sheet

Project title: Researching which aspects of urban green spaces are important for younger and older people

Lead researcher: Rebecca Reece

You are invited to take part in research taking part at the University of the West of England, Bristol. It is funded by the Economic and Social Research Council (ESRC), through the South West Doctoral Training Partnership (SWDTP). Before you decide, it is important for you to understand why the research is being done and what it will involve. Please read this information sheet carefully. If you have any questions or would like more information please contact Rebecca Reece, Faculty of HAS, University of the West of England, Bristol [Rebecca.Reece@uwe.ac.uk]. Please take time to decide whether you wish to take part.

Who is organising and funding the research?

The lead researcher for this project is Rebecca Reece. This project is part of an SWDTP PhD funded by the ESRC. Supervisors for this project include; Dr Chris Alford (Director of Studies) (Chris.Alford@uwe.ac.uk), Dr Issy Bray (Issy.Bray@uwe.ac.uk), and Dr Lewis Elliott).

What is the aim of the research?

The reason for this study is to understand which aspects of our green spaces in the city are important to users. For example, parks, green corridors such as cycle paths, canals, rivers, community gardens, allotments, etc. Also, how these features could work for both young and older people sharing the same space. We are interested in understanding what you enjoy, or may not enjoy, about these spaces. We are also interested in what you see visually in these spaces, as well as what you hear/smell/touch and feel. Finally, we would like to understand how people's wellbeing is when they are in these spaces, how they can change your feelings and emotions. To help us understand this, we will be conducting interviews. The aim of the interviews will be to collect information - this will be made anonymous.

The results of our study will be analysed and included in the lead researcher's PhD thesis. The anonymised results may be used in conferences and peer-reviewed research papers. Therefore, any information presented cannot be linked to the people who took part.

Why have I been invited to take part?

As a regular visitor of urban green spaces, we are interested in understanding your opinions of visiting these spaces and the features of these spaces that you enjoy. The interview will

ask you about these things. We also want to understand the opinions from people of different ages.

Do I have to take part?

You do not have to take part. It is up to you whether or not you want to be involved. If you do decide to take part, you will be given a copy of this information sheet to keep. You will also be asked to provide consent via a webpage. If you are under 18 years old, your parent or legal guardian will also be asked to provide verbal consent during the interview on your behalf. If you decide to take part, you can withdraw from the research without giving a reason. You can do this up to 1 week from the date you provided consent. If you want to withdraw from the study within this time, please email Rebecca Reece (Rebecca.Reece@uwe.ac.uk). There is no penalty if you do not want to take part or want to withdraw from the study.

What will happen to me if I take part and what do I have to do?

If you agree to take part, you will be asked to take part in an interview. This will be with the lead researcher (Rebecca Reece). The researcher, and supervisors, are experienced in the subject topic. They are sensitive to issues it may raise. The interview will take approximately 45mins-1hr. The interview will take place online using Zoom. You will be emailed a link to join the session. At the beginning of the interview you will be asked to provide your age, gender, and ethnicity.

The subject and focus of the discussion will be around your visits to urban green spaces. It will also be about features of those spaces which you may like/dislike.

Your interview will be audio recorded through Zoom. The recording will not contain your name. A unique identifier will be used to re-identify you if you choose to withdraw from the study. This will enable your data to be deleted. Once transcribed, your voice recording will be deleted. Your data will be anonymised at this point so that it cannot be linked to you. Your data will be analysed with data from other anonymous participants.

What are the benefits of taking part?

The information you provide will give us a better understanding of how urban green spaces can affect users. Also, we will understand what features of these spaces are important for people of different ages. By knowing this, it can help us use and design better spaces.

What are the possible risks of taking part?

We do not anticipate any significant risk to you in taking part in this study. If, however, you feel uncomfortable at any time you can ask for the interview to stop. You are also free to take a short break if you need one, just let the interviewer know. If you need any support during or after the interview, the researcher will put you in touch with suitable support. The research team are experienced in conducting interviews and are sensitive to the subject area. The interview has been designed with these considerations in mind.

What will happen to your information?

All information we receive from you will be treated in the strictest confidence. Only the lead researcher will have access to your name in the first instance. You will not be personally identified in any report, thesis, or publication of results. All information is confidential. Your interview recording and transcription will be anonymised. This will be so that you cannot be recognised from it. Voice recordings will be destroyed securely immediately after

anonymised transcription into a written record. Your anonymised data will be analysed together with other participants data. We will make sure there is no chance of identification or re-identification after this point.

All anonymised data will be held for as long as it has research value. This will not exceed 10 years. Anonymised data will be stored on UWE OneDrive. Only the lead researcher and supervisors will have access. This is in line with the University's requirements and the Data Protection Act 2018 and General Data Protection Regulation requirements.

Where will the results of the research study be published?

A report will be written containing our research findings. This report will be included in the lead researcher's PhD thesis. The project funder is the ESRC.

A copy of the report will be available to all participants if you would like to see it. Key findings will also be shared both within and outside UWE. Anonymous and nonidentifying quotes may be used in publications and presentations. No data will be published that could identify individual participants.

Who has ethically approved this research?

The project has been reviewed and approved by the Faculty Research Ethics Committee (FREC) at UWE, Bristol. Any comments, questions or complaints about the ethical conduct of this study can be addressed to the Research Ethics Committee at the University of the West of England at: Researchethics@uwe.ac.uk

What if something goes wrong?

If something goes wrong, and then leads to a complaint, the Director of Studies will be informed.

What if I have more questions or do not understand something?

If you would like any further information about the research, please contact:

Lead researcher: Rebecca Reece

Email: Rebecca.Reece@uwe.ac.uk

Thank you for volunteering for this study.

You will be given a copy of this Participant Information Sheet to keep.

Privacy Notice for Research Participants

Project title: Researching which aspects of urban green spaces are important for younger and older people.

Purpose of the Privacy Notice

This privacy notice explains how the University of the West of England, Bristol (UWE Bristol) collects, manages and uses your personal data before, during and after you participate in *'Researching which aspects of urban green spaces are important for younger and older people'*. 'Personal data' means any information relating to an identified or identifiable natural person (the data subject). An 'identifiable natural person' is one who can be identified, directly or indirectly. This can include by reference to an identifier such as a name, an identification number, location data, an online identifier. Or this can include to one or more factors specific to the physical, physiological, genetic, mental, economic, cultural or social identity of that natural person.

This privacy notice adheres to the General Data Protection Regulation (GDPR) principle of transparency. This means it gives information about:

- How and why your data will be used for the research;
- What your rights are under GDPR; and
- How to contact UWE Bristol and the project lead in relation to questions, concerns or exercising your rights regarding the use of your personal data.

This Privacy Notice should be read in conjunction with the Participant Information Sheet and Consent Form. These are provided to you before you agree to take part in the research. **Why are we processing your personal data?**

UWE Bristol undertakes research as a public organisation to provide research for the benefit of society. As a data controller, we are committed to protecting the privacy and security of your personal data. This is in accordance with the (EU) 2016/679 the General Data Protection Regulation (GDPR), the Data Protection Act 2018 (or any successor legislation) and any other legislation directly relating to privacy laws that apply (together "the Data Protection Legislation"). General information on Data Protection law is available from the Information Commissioner's Office (<https://ico.org.uk/>).

How do we use your personal data?

We use your personal data for research with appropriate safeguards in place on the lawful bases of fulfilling tasks in the public interest. And for archiving purposes in the public interest, for scientific or historical research purposes.

We will always tell you about the information we wish to collect from you and how we will use it. We will not use your personal data for automated decision making about you or for profiling purposes.

Our research is governed by robust policies and procedures. Where human participants are involved, is subject to ethical approval from either UWE Bristol's Faculty or University Research Ethics Committees. This research has been approved by the Faculty of Health and Applied Sciences Research Ethics Committee. The research team adhere to the **Ethical guidelines of the British Educational Research Association (and/or the principles of the Declaration of Helsinki, 2013) and the principles of the General Data Protection Regulation (GDPR).**

For more information about UWE Bristol's research ethics approval process please see our Research Ethics webpages at: www1.uwe.ac.uk/research/researchethics

What data do we collect?

The data we collect will vary from project to project. Researchers will only collect data that is essential for their project. The specific categories of personal data processed are described in the Participant Information Sheet provided to you with this Privacy Notice. **Who do we share your data with?**

We will only share your personal data in accordance with the attached Participant Information Sheet and your Consent.

How do we keep your data secure?

We take a robust approach to protecting your information. This includes secure electronic and physical storage areas for research data with controlled access. If you are participating in a particularly sensitive project, UWE Bristol puts into place additional layers of security. UWE Bristol has Cyber Essentials information security certification.

Alongside these technical measures there are comprehensive and effective policies and processes in place. These are to make sure that users and administrators of information are aware of their obligations and responsibilities for the data they have access to.

By default, people are only granted access to the information they require to perform their duties. Mandatory data protection and information security training is provided to staff. Expert advice is available if needed.

How long do we keep your data for?

Your personal data will only be retained for as long as is necessary, to fulfil the cited purpose of the research. The length of time we keep your personal data will depend on several

things. These include the significance of the data, funder requirements, and the nature of the study. Specific details are provided in the Participant Information Sheet.

Anonymised data that falls outside the scope of data protection legislation as it contains no identifying or identifiable information may be stored in UWE Bristol's research data archive or another carefully selected appropriate data archive. **Your Rights and how to exercise them**

Under the Data Protection legislation, you have the following **qualified** rights:

- (1) The right to access your personal data held by or on behalf of the University;
- (2) The right to rectification if the information is inaccurate or incomplete;
- (3) The right to restrict processing and/or erasure of your personal data;
- (4) The right to data portability;
- (5) The right to object to processing;
- (6) The right to object to automated decision making and profiling; (7) The right to [complain](#) to the Information Commissioner's Office (ICO).

We will always respond to concerns or queries you may have. If you wish to exercise your rights or have any other general data protection queries, please contact UWE Bristol's Data Protection Officer (dataprotection@uwe.ac.uk).

If you have any complaints or queries relating to the research in which you are taking part please contact either the research project lead, whose details are in the attached Participant Information Sheet or UWE Bristol's research governance manager (researchgovernance@uwe.ac.uk).

Appendix 5. Chapter 3 interview questions

Introductory questions

- Do you visit urban green spaces (e.g. these can include parks, green corridors such as cycle paths, canals, rivers, community gardens, allotments)? *Follow-up: why do you visit them?*
- How often do you visit urban green spaces?
Prompt: daily, once a week, as often as I can, etc?
- How close is your nearest urban green space or urban green space that you tend to visit?
Prompt: how long does it take to reach your nearest urban green space?
Follow-up: is it easily accessible for you?

Main questions

Important components/features of urban green spaces

- Why do you visit urban green spaces?
- What features of urban green spaces do you like and why? *Follow-up: What do you dislike and why?*

Urban green spaces and wellbeing

- How do you feel when you are in urban green spaces?
Follow-up: How do you feel after visiting an urban green space?
- Do you think visiting an urban green space has an impact on your mental wellbeing? If so, in what way?
Prompt: does it have a positive/negative impact?
- Are there any features of an urban green space that you think contribute to your mental wellbeing?
Prompt: do some features make you feel happy/sad etc?

Multi-sensory focus

- What do you **see** when you are in urban green spaces?
Prompt: (e.g. trees, flowers, playground, wildlife, people)
- What do you **hear** when you are in urban green spaces?
Prompt: (e.g. birdsong, running water, people, dogs, city/traffic)
- What do you **smell** when you are in urban green spaces? *Prompt: (e.g. freshly cut grass, café, fresh air)*
- What do you **feel** when you are in urban green spaces?
Prompt: (e.g. grass, tree bark, wind/breeze, sun on skin, temperature)
- When you visit an urban green space, do you feel immersed in the environment?
Follow-up: If so, what is it about the environment that makes you feel immersed?

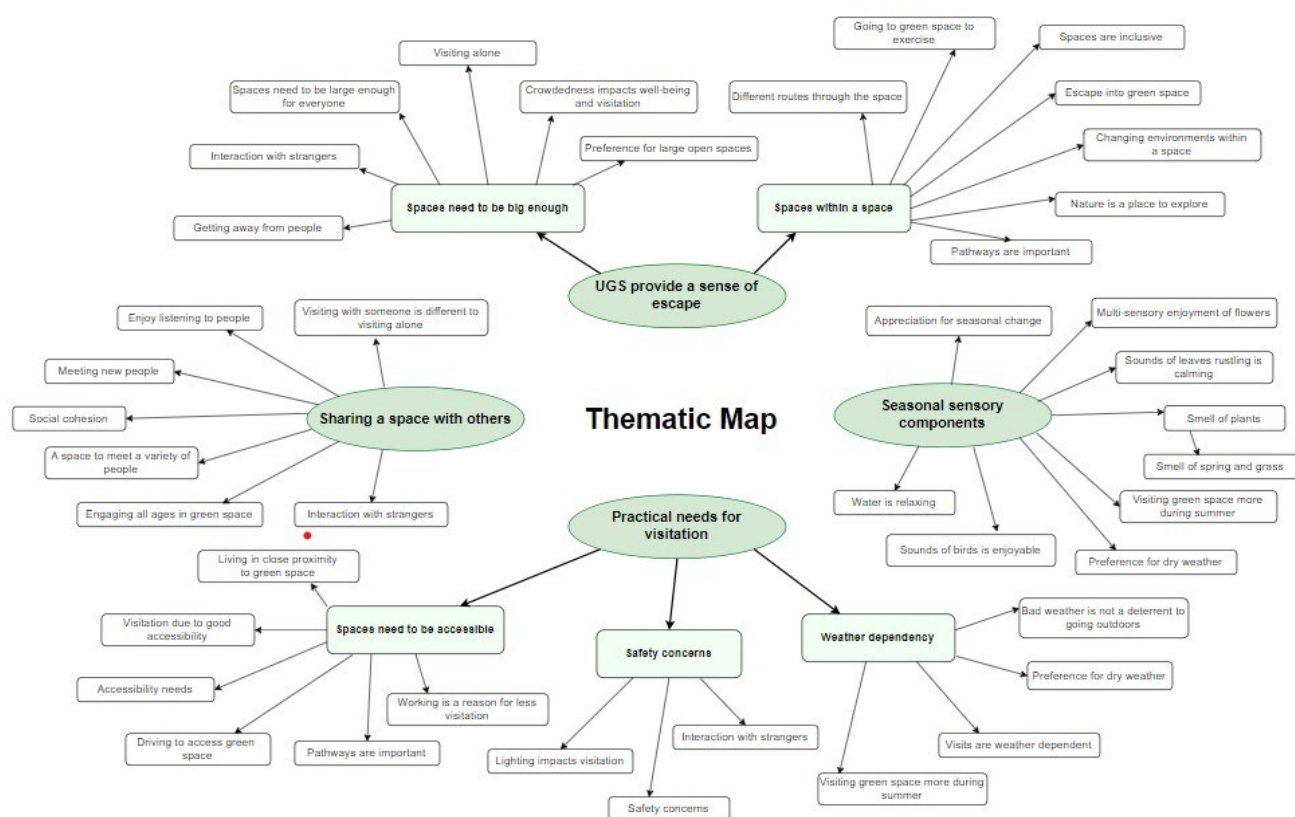
Reasons for visitation and ideal space

- What is it about an urban green space that would motivate/deter you to visit?
- Imagine you are a tour guide walking through your ideal urban green space, how would you explain it?
Prompt: What features would it have?
Prompt: Would it be a multi-sensory space/experience?
- When you visit urban green spaces, do you go with other people? If so, are they the same age as you?
- Do you mix with people of other ages in urban green spaces?

Closing questions

- Thank you very much for your responses, is there anything more you would like to add?
- Is there anything you would like to ask me?

Appendix 6. Chapter 3 thematic map



Appendix 7. Chapter 3 publication additional content

Funding sources

This research was part of a PhD studentship (part of a thesis) at the University of the West of England and funded by the Economic and Social Research Council through the South West Doctoral Training Partnership (SWDTP studentship grant reference: ES-P000630-1).

Ethics statement

The study was approved by the University of the West of England's Faculty Research Ethics Committee (UWE FREC no: HAS.22.04.091). All participants involved in this research provided informed consent before taking part (see consent form below).

Consent form

Researching which aspects of urban greenspaces are important for younger and older people. You are invited to take part in an interview as part of a research project at the University of the West of England. The purpose of this study is to identify and understand which features of urban greenspaces (e.g., a park or a community garden), are preferred and valuable to your mental well-being. Please ensure that you have read and understood the information contained in the Participant Information Sheet and asked any questions before you provide consent. If you have any questions please contact a member of the research team, whose details are set out on the Participant Information Sheet. If you are happy to take part in this interview, please click the next arrow at the bottom of this page. By clicking this, you are providing consent and agree to the following statements:

- I have read and understood the information in the Participant Information Sheet which I have been given to read before asked to sign this form.
- I have been given the opportunity to ask questions about the study.
- I have had my questions answered satisfactorily by the research team.
- I understand that I will be audio-recorded, and the recording will be destroyed once the data has been transcribed for analysis.
- I agree that anonymised quotes may be used in the final report of this study.
- I understand that my participation is voluntary and that I am free to withdraw at any time until the data has been anonymised, without giving a reason.
- I agree to take part in the research.

Authorship statement

Rebecca Reece: Conceptualization, Data curation, Formal analysis, Funding acquisition, Methodology, Writing – original draft, Writing – review & editing. Lewis Elliott: Conceptualization, Methodology, Supervision, Writing – review & editing. Isabelle Bray: Conceptualization, Methodology, Supervision, Writing – review & editing. Anna Bornioli: Methodology, Writing – review & editing.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

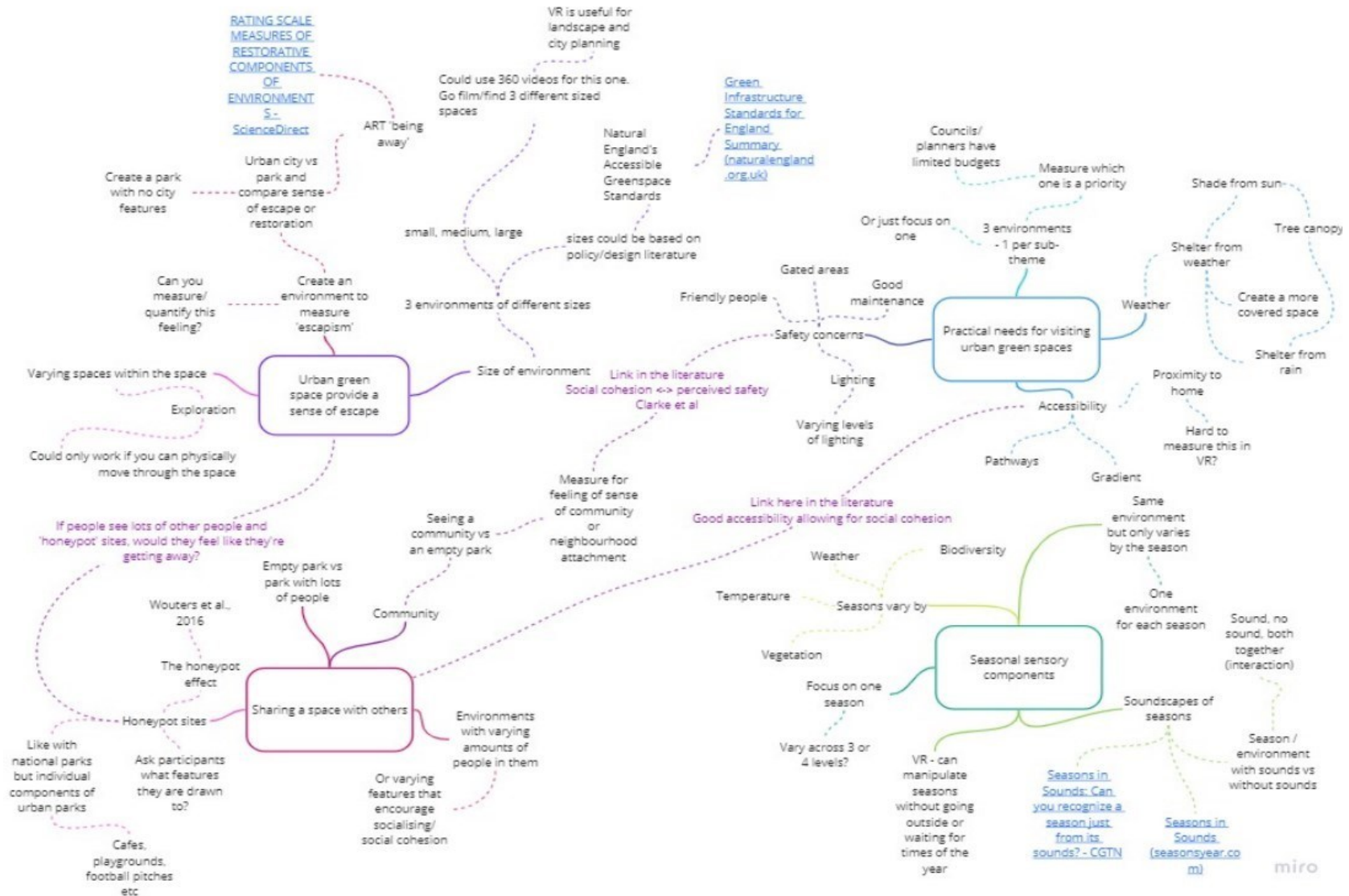
Acknowledgements

We would like to thank the anonymous participants for taking part in this research.

Supplementary materials

Supplementary material associated with this article can be found, in the online version, at [doi:10.1016/j.wss.2024.100206](https://doi.org/10.1016/j.wss.2024.100206).

Appendix 8. Chapter 3 mind map



Appendix 9. Chapter 4 extended methods

Sample size

The sample size for this study included 35 participants. This sample size is justified by multiple factors. The first being the length and involvement of this experiment. Participants were required to come to the laboratory for 1.5 hours to take part. This was an intensive study in terms of participant commitment and involvement which influences the duration of the data collection phase for the study and the scope of what can be achieved in a realistic timeframe. A further justification for this sample size was that previous psychological experimental studies, focused on restorative environments, have also adopted similar sample sizes (Chen et al., 2020; Roe et al., 2013).

Study design

This experimental study used a within-subjects design in that all participants were subjected to all conditions/levels of the experiment. All participants viewed all environmental stimuli (green historic, green modern, non-green historic, non-green modern). Within-subjects design have an advantage in that they have strong statistical power whilst also being practically advantageous in requiring smaller sample sizes (Charness et al., 2012). But within-subjects designs have the disadvantage of being prone to eliciting demand effects whereby participants change their behaviour or answers based on what they think the goal or intentions of the researcher or study are (Charness et al., 2012). To avoid this, the order in which the environments were shown were counterbalanced, and participants were not able to go back in the questionnaire to change their answers. Whilst the purpose of the study was not hidden from participants, participants were not told the expected direction of effect which the study might result in, so to not influence the responses to the questionnaire. These procedures were put in place to reduce the possibility of demand characteristics, however it is not certain that these were eliminated entirely.

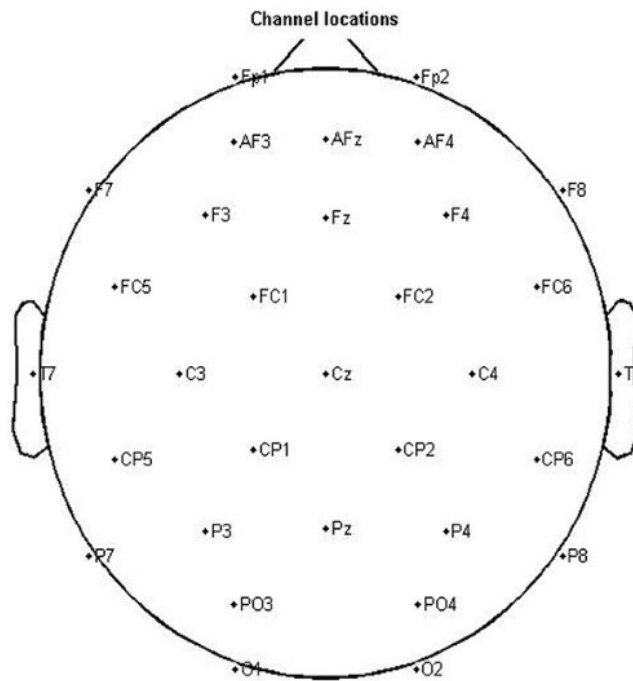
Data analysis

For the quantitative subjective data, a linear mixed-effects model (LLM) was chosen to analyse the questionnaire data. In the psychological sciences, LLMs have become a prominent data analysis technique (Meteyard & Davies, 2020). They are commonly used when a study has adopted a repeated measures/within-subjects design. This study had a within-subjects design and so initially this choice for data analysis was an option. Looking further, LLMs go beyond a simple linear model by incorporating both fixed and random effects. The definitions

for fixed and random effects are complex and debated but generally fixed effects are defined as parameters which do not vary, whereas random effects are parameters which are random variables. The only random effect included for in the model was the participant (ID/number).

For the EEG analysis, spectral analysis was chosen as an appropriate way in which to analyse brain activity. EEG is a mixture of neural oscillations and spectral analysis can be used to quantify the rhythmic activity of frequencies (Kim & Im, 2018). Brain activity is transformed into the frequency (spectral) domain which allows for analysis of the oscillations and power of the different frequency bands (alpha, beta, theta, gamma). In order to convert the time domain EEG signals into the frequency domain and measure the power spectral density, a common method is by using the Fast Fourier Transform (FFT). EEG data is complex and contains a large amount of noise and FFT can be beneficial in simplifying this data and allowing for interpretation of frequencies.

Due to the nature of the stimuli in this experiment being visual and the outcome of interest being well-being, the focus of the EEG analysis was placed on the occipital and frontal regions of the brain only. The occipital lobe is mainly responsible for visual processing and is therefore an important area to focus on when using visual stimuli, like in this experiment with the environment videos. Moreover, the frontal lobe (specifically the prefrontal lobe) is a responsible area for functions such as emotional processing, mood and attention (Dolcos et al., 2018) (see below for placement of electrodes).



32 of 32 electrode locations shown

Stimuli

Prior to participants viewing the environment videos, they first were subjected to a stressor to bring participants to a negative state. Including a stressor condition prior to an environmental condition is a common practice in experimental studies in psychology

(Ferreira, 2019). Common stressors often used in studies include the Trier Social Stress Test (Wang et al., 2019) and mental arithmetic and memory tests (Huang et al., 2020; Yin et al., 2020). A limitation of these stressors is that they are time consuming and therefore extend the amount of time which participants are involved with the study. For this experiment, whereby participants would view several environmental conditions as well as wait for the EEG equipment to be set-up, pragmatically a shorter stressor was required. Due to these requirements, the stressor used in the study was a video of heavy motorway traffic with the accompanying loud, stressful audio. The audio of the video was also included due to the increase in stress that this was thought to create. Previous studies have demonstrated the negative impact that road traffic noise can have on well-being (Bluhm et al., 2007; Öhrström et al., 2006; Singh et al., 2018). Brain activity, as measured using EEG, has also been found to be impacted by the noise of road traffic (Manohare et al., 2023). It was important for controlling extraneous variables that the traffic video shown represented traffic in the UK.

To keep in line with the environment videos, which were of spaces in the UK, the traffic was also of traffic in the UK (the M5 motorway).

Appendix 10. Chapter 4 ethical approval



Faculty of Health & Applied
Sciences
Glenside Campus
Blackberry Hill
Stapleton
Bristol BS16 1DD

Tel: 0117 328 1170

UWE REC REF No: HAS.19.08.005 Bornioli

1 October 2019

Dr Anna Bornioli
Research Fellow and Lecturer in Public Health
Centre for Public Health and Wellbeing (CPHWB)
Department of Health and Social Sciences
Faculty of Health and Applied Sciences
Frenchay Campus, room 3L07

Dear Anna

Application title: Urban environments and mental wellbeing: an EEG study

Your ethics application was considered by the Faculty Research Ethics Committee and, based on the information provided, has been given ethical approval to proceed.

Note to researcher: please ensure you read and follow the guidance on the [use of social media in research](#).

The following standard conditions also apply to all research given ethical approval by a UWE Research Ethics Committee:

1. You must notify the relevant UWE Research Ethics Committee in advance if you wish to make significant amendments to the original application: these include any changes to the study protocol which have an ethical dimension. Please note that any changes approved by an external research ethics committee must also be communicated to the relevant UWE committee. Amendments should be requested using the form at <http://www1.uwe.ac.uk/research/researchethics/applyingforapproval.aspx>
2. You must notify the University Research Ethics Committee if you terminate your research before completion;
3. You must notify the University Research Ethics Committee if there are any serious events or developments in the research that have an ethical dimension.

The Faculty and University Research Ethics Committees (FRECs and UREC) are here to advise researchers on the ethical conduct of research projects and to approve projects that meet UWE's ethical standards. Please note that we are unable to give advice in relation to legal issues, including health and safety, privacy or data protection (including GDPR) compliance. Whilst we will use our best endeavours to identify and notify you of any obvious legal issues that arise in an application, the lead researcher remains responsible for ensuring that the project complies with UWE's policies, and

with relevant legislation <https://intranet.uwe.ac.uk/whats-happening/sites/gdpr/updates/pages/research-and-gdpr-compliance-update-08-may-2019.aspx>. If you need help with legal issues please contact safety@uwe.ac.uk (for Health and Safety advice), James2.Button@uwe.ac.uk (for data protection, GDPR and privacy advice).

Please note: The UREC is required to monitor and audit the ethical conduct of research involving human participants, data and tissue conducted by academic staff, students and researchers. Your project may be selected for audit from the research projects submitted to and approved by the UREC and its committees.

Please remember to populate the HAS Research Governance Record with your ethics outcome via the following link: <https://teams.uwe.ac.uk/sites/HASgovernance>.

We wish you well with your research.

Yours sincerely

Dr Julie Woodley
Chair
Faculty Research Ethics Committee

c.c. *(supervisor, where applicable)*

Appendix 11. Chapter 4 consent form

Consent form

Project title: Urban environments and mental wellbeing: an EEG study

Principal investigator: Issy Bray

This consent form will have been given to you with the Participant Information Sheet. Please ensure that you have read and understood the information contained in the Participant Information Sheet and asked any questions before you sign this form. If you have any questions please contact a member of the research team, whose details are set out on the Participant Information Sheet.

If you are happy to take part, please sign and date the form. You will be given a copy to keep for your records. Please tick all the relevant boxes:

- ☐ I have read and understood the information in the Participant Information Sheet which I have been given to read before being asked to sign this form;
- ☐ I have been given the opportunity to ask questions about the study;
- ☐ I have had my questions answered satisfactorily by the research team;
- ☐ I understand the nature and purpose of the procedures involved communicated to me on a separate information sheet and in discussion with the researchers;
- ☐ I understand that a unique code will replace my name so that my data can remain confidential and that I will not be identified in any way when the research is published;
- ☐ I agree to the principal investigator recording and processing the data I provide during the course of the study unless I state otherwise. I understand that this information will be used only for the purpose set out in the information sheet, and my consent is conditional upon the University complying with its duties and obligations under the Data Protection Act.
- ☐ I understand that EEG electrodes will be placed on my head to measure brain activity, and on my hands and wrists to measure other physiological activity (skin responses and heart rate);
- ☐ I have checked that I meet the inclusion criteria and am not excluded by the exclusion criteria;
- ☐ I understand that I can ask questions about the study after I have completed the experiment;
- ☐ I understand that I am free to withdraw from the study at any time;
- ☐ I understand that I am free to withdraw from the study without having to give a reason for withdrawing;
- ☐ I understand that I am free to withdraw my data from any future analysis/or publication, provided that I inform the principal investigator within one week of the date from when this form is signed and without needing to give a reason;
- ☐ I understand that my data may be stored for up to 10-years and used in research publications, but my data will remain anonymous;
- ☐ I agree to take part in the research.

I fully and freely consent to participate in a study entitled: Urban environments and mental wellbeing: an EEG study

Signature of participant:

Date: -

Information Sheet

Project title: Urban environments and mental wellbeing: an EEG study

Principal investigator: Dr Issy Bray

You are being invited to take part in a research study. Before you decide to take part it is important for you to understand why the research is being done and what it will involve. Please take time reading the following information carefully and discuss it with others if you wish. Please ask the principal investigator if anything is not clear or if you would like more information. Take time to decide whether you wish to take part.

What is the purpose of this research?

The purpose of the research is to investigate **people's responses in different urban environments**. If we can identify environments that are good for individuals' mental wellbeing, this will have important implications for real-world situations.

Why have I been asked and do I have to take part?

There are several **exclusion and inclusion criteria**. Please read through them carefully and consider whether you are eligible to take part in this study.

Persons eligible to take part:

- Healthy volunteers
- Fluent in English

Persons not eligible to take part:

- Suffer from skin allergy or hypersensitive skin (you may react to the electrodes or electrolyte)
- Have experienced an epileptic seizure within the past 12-months
- Have current or previous hypertension, anxiety, psychiatric, or neurological disorders, or current illness (e.g. influenza)
- Taking prescribed medication for brain or psychiatric conditions (e.g. anxiety, depression or epilepsy)

It is up to you to decide whether to take part. If you do decide to take part, you will be given this information sheet to keep and be asked to sign a consent form. If you decide to take part, you are still free to withdraw at any time and without giving a reason.

Psychology students who participate will be eligible to receive **2 course credits** for completing the study, in keeping with standard practice for psychology undergraduate course participation. Psychology students have the choice of many studies to participate in, and so do not have to take part in this study if they do not wish to. Psychology students will

still be eligible to receive the course credit if they decide to withdraw at any time during the study.

How will the research be done and what will I have to do?

If you do decide to take part, we will ask you to come into the laboratory on one occasion for approximately **two hours**.

When you first arrive, the procedure will be explained and you will be asked to confirm that you are happy to proceed.

If you are happy to continue, the physiological recording equipment will be set up.

Set up of physiological recording equipment

We are interested in measuring brain activity (electroencephalography; EEG) and physiological responses (heart rate, blood pressure, skin response). Measuring brain and body physiology is of great interest to many researchers. Directly measuring the body and brain in real time can provide us with insights into cognitive functioning, such as perception, attention, and language processing. EEG and associated physiological measurements are very commonly performed and are routinely used in research and clinical assessments in the NHS. They have been used safely for many decades. All equipment comes from certified suppliers, who are obliged by law to adhere to published guidelines on electrical and mechanical safety.

Using EEG equipment, we will measure the electrical activity of your brain. EEG measures the electrical voltage signals of brain activity directly from sensors that touch the scalp. Sensor placement and preparation typically requires 45 minutes. A snug fitting cap made of an elasticated cloth material containing sensors will be placed on your head. Next, a gel that contains salt will be placed between each sensor and the scalp. This provides a better signal of the brain activity. The procedure doesn't cause pain or harm, but it may feel a little unusual as you are wearing a snug fitting cap – like a swimming cap.

If you do feel any discomfort at any time, please let the principle investigator know and the study can be stopped at any time.

Using the Biopac equipment, we will measure Galvanic Skin Response (GSR), Blood Volume Pulse (BVP), Acceleration, Heart Rate (HR), and Temperature. The procedure entails wearing hand equipment including stick-on electrodes and this doesn't cause pain, but if you do feel any discomfort at any time, please let the principle investigator know and the study can be stopped.

Tasks

Once the equipment is set up, the experiment will begin, and you will be asked to complete a **questionnaire** that includes several videos. Continual recordings of your physiological signals will be recorded while you are watching the videos. The videos last 21 minutes in total and you will be asked to complete rating scales between videos, but you will be able to take breaks between the different sequences.

Once the task finishes the equipment will be removed. You are able to wash your hair, and shampoo and combs as well as towels are provided. There may be some slight discomfort when the electrodes are removed from your skin – similar to removing a sticking plaster – and some people may develop a mild transitory rash where the electrodes were attached.

Is this information confidential and held securely, and what will be done with the results?

All data which leaves the laboratory will have your name removed and will be anonymised so that you cannot be recognised from it. You will not be personally identified in any report, thesis, or publication of results. All information is confidential.

All data will be held for as long as it retains research value although this will not exceed 10-years. The anonymised data may be made available for further appropriately approved research through the University. No data will be published in a way that could identify individual participants.

The general results will be available from June 2020, thus if you wish to obtain a copy of the summary results please contact the principal investigator.

What happens if I have a complaint?

If something goes wrong, and consequently leads to a complaint, the Project Principal Investigator will be informed.

Do you have any further questions?

If you have questions about the research - either now or at some future date - please contact the researchers.

Contact details:

Researchers:

Becky Reece: rebecca.reece@uwe.ac.uk

Anna Bornioli: anna.bornioli@uwe.ac.uk

Principal investigator: Issy Bray

Email: issy.bray@uwe.ac.uk

Co-investigator: Chris Alford

Email: Chris.Alford@uwe.ac.uk

Purpose of the Privacy Notice

This privacy notice explains how the University of the West of England, Bristol (UWE) collects, manages and uses your personal data before, during and after you participate in Urban environments and mental wellbeing: an EEG study. 'Personal data' means any information relating to an identified or identifiable natural person (the data subject). An 'identifiable natural person' is one who can be identified, directly or indirectly, including by reference to an identifier such as a name, an identification number, location data, an online identifier, or to one or more factors specific to the physical, physiological, genetic, mental, economic, cultural or social identity of that natural person.

This privacy notice adheres to the General Data Protection Regulation (GDPR) principle of transparency. This means it gives information about:

- How and why your data will be used for the research;
- What your rights are under GDPR; and
- How to contact UWE Bristol and the project lead in relation to questions, concerns or exercising your rights regarding the use of your personal data.

This Privacy Notice should be read in conjunction with the Participant Information Sheet and Consent Form provided to you before you agree to take part in the research.

Why are we processing your personal data?

UWE Bristol undertakes research under its public function to provide research for the benefit of society. As a data controller we are committed to protecting the privacy and security of your personal data in accordance with the (EU) 2016/679 the General Data Protection Regulation (GDPR), the Data Protection Act 2018 (or any successor legislation) and any other legislation directly relating to privacy laws that apply (together “the Data Protection Legislation”). General information on Data Protection law is available from the Information Commissioner’s Office (<https://ico.org.uk/>).

How do we use your personal data?

We use your personal data for research with appropriate safeguards in place on the lawful bases of fulfilling tasks in the public interest, and for archiving purposes in the public interest, for scientific or historical research purposes.

We will always tell you about the information we wish to collect from you and how we will use it.

We will not use your personal data for automated decision making about you or for profiling purposes.

Our research is governed by robust policies and procedures and, where human participants are involved, is subject to ethical approval from either UWE Bristol’s Faculty or University Research Ethics Committees. This research has been approved by the Faculty of Health and Applied Sciences Research Ethics Committee. The research team adhere to the Ethical guidelines of the British Educational Research Association (and/or the principles of the Declaration of Helsinki, 2013) and the principles of the General Data Protection Regulation (GDPR).

For more information about UWE Bristol’s research ethics approval process please see our Research Ethics webpages at:

www1.uwe.ac.uk/research/researchethics **What**

data do we collect?

The data we collect will vary from project to project. Researchers will only collect data that is essential for their project. The specific categories of personal data processed are described in the Participant Information Sheet provided to you with this Privacy Notice

Who do we share your data with?

We will only share your personal data in accordance with the attached Participant Information Sheet and your Consent.

How do we keep your data secure?

We take a robust approach to protecting your information with secure electronic and physical storage areas for research data with controlled access. If you are participating in a particularly sensitive project UWE Bristol puts into place additional layers of security. UWE Bristol has Cyber Essentials information security certification.

Alongside these technical measures there are comprehensive and effective policies and processes in place to ensure that users and administrators of information are aware of their obligations and responsibilities for the data they have access to. By default, people are only granted access to the information they require to perform their duties. Mandatory data protection and information security training is provided to staff and expert advice available if needed.

How long do we keep your data for?

Your personal data will only be retained for as long as is necessary to fulfil the cited purpose of the research. The length of time we keep your personal data will depend on several factors including the significance of the data, funder requirements, and the nature of the study. Specific details are provided in the attached Participant Information Sheet. Anonymised data that falls outside the scope of data protection legislation as it contains no identifying or identifiable information may be stored in UWE Bristol's research data archive or another carefully selected appropriate data archive.

Your Rights and how to exercise them

Under the Data Protection legislation you have the following qualified rights:

- (8) The right to access your personal data held by or on behalf of the University;
- (9) The right to rectification if the information is inaccurate or incomplete;
- (10) The right to restrict processing and/or erasure of your personal data;
- (11) The right to data portability;
- (12) The right to object to processing;
- (13) The right to object to automated decision making and profiling;
- (14) The right to [complain](#) to the Information Commissioner's Office (ICO).

Please note, however, that some of these rights do not apply when the data is being used for research purposes if appropriate safeguards have been put in place.

We will always respond to concerns or queries you may have. If you wish to exercise your rights or have any other general data protection queries, please contact UWE Bristol's Data Protection Officer (dataprotection@uwe.ac.uk).

If you have any complaints or queries relating to the research in which you are taking part please contact either the research project lead, whose details are in the attached Participant Information Sheet, UWE Bristol's Research Ethics Committees (research.ethics@uwe.ac.uk) or UWE Bristol's research governance manager (Ros.Rouse@uwe.ac.uk)

Appendix 13. Chapter 4 questionnaire

Start of Block: Introduction

You are being invited to take part in a research study exploring the experience of **exposure to different urban areas**. You will be required to watch a series of videos and answer some questions. Participation is entirely **voluntary** and **anonymous**. You will be awarded **2 psychology participation credits** in exchange of your participation. The experiment will take a maximum of 2 hours, including the time to set up the EEG. The total length of the videos you will watch is 21 minutes. You are free to take a break after each video/question sequence before moving onto the next.

You can **withdraw** at any time with no consequences and without providing a reason. You can **withdraw** your data by contacting the research team within one week from today. By clicking the Next button you are confirming your **consent** to the use of data. Full information can be found on the **information sheet**. If you have any questions please ask any of the researchers.

Please now remember your participant code. The researcher will tell you your participant code now.

End of Block: Participant code

Start of Block: Traffic video 1

Please watch the first video before continuing.

End of Block: Traffic video 1

Start of Block: Mood - After traffic video 1

How do you feel now?

In each case move the 'slide' underneath the word at the top that best explains how you feel about each of the emotions in the list on the left hand side.

	Definitely not	Not much	Quite	Definitely
	1	2	3	4
Relaxed ()				

Happy ()	
Sad ()	
Nervous ()	

End of Block: Mood - After traffic video 1

Start of Block: Enviro video 1

Please watch the next video before continuing.

End of Block: Enviro video 1

Start of Block: Mood - After enviro video 1

How do you feel now?

In each case move the 'slide' underneath the word at the top that best explains how you feel about each of the emotions in the list on the left hand side.

	Definitely not	Not much	Quite	Definitely
	1	2	3	4
Relaxed ()				
Happy ()				
Sad ()				
Nervous ()				

End of Block: Mood - After enviro video 1

Start of Block: Traffic video 2

Please watch the next video before continuing.

End of Block: Traffic video 2

Start of Block: Enviro video 2

Please watch the next video before continuing.

End of Block: Enviro video 2

Start of Block: Mood - After enviro video 2

How do you feel now?

In each case move the 'slide' underneath the word at the top that best explains how you feel about each of the emotions in the list on the left hand side.

		Definitely not	Not much	Quite	Definitely
		1	2	3	4
Relaxed ()					
Happy ()					
Sad ()					
Nervous ()					

End of Block: Mood - After enviro video 2

Start of Block: Traffic video 3

Please watch the next video before continuing.

End of Block: Traffic video 3

Start of Block: Enviro video 3

Please watch the next video before continuing.

End of Block: Enviro video 3

Start of Block: Mood - After enviro video 3

How do you feel now?

In each case move the 'slide' underneath the word at the top that best explains how you feel about each of the emotions in the list on the left hand side.

Definitely Not much Quite Definitely
not

		1	2	3	4
Relaxed ()					
Happy ()					
Sad ()					
Nervous ()					

End of Block: Mood - After enviro video 3

Start of Block: Traffic video 4

Please watch the next video before continuing.

End of Block: Traffic video 4

Start of Block: Enviro video 4

Please watch the next video before continuing.

End of Block: Enviro video 4

Start of Block: Mood - After enviro video 4

How do you feel now?

In each case move the 'slide' underneath the word at the top that best explains how you feel about each of the emotions in the list on the left hand side.

		Definitely not	Not much	Quite	Definitely
		1	2	3	4
Relaxed ()					
Happy ()					
Sad ()					
Nervous ()					

End of Block: Mood - After enviro video 4

Start of Block: End of videos

That is the end of the videos, thank you for watching. Before finishing, please answer the next few questions.

End of Block: End of videos

Start of Block: Descriptors3

How would you describe the place in the photo? Please choose maximum 3 words from the list below:

	Pick a maximum 3 descriptors (1)
1: green (53)	
2: urban (54)	
3: historic (55)	
4: natural (56)	
5: old (57)	
6: modern (58)	
7: new (59)	
8: attractive (60)	
9: cultural (61)	
10: built (62)	

End of Block: Descriptors3

Start of Block: Descriptors2

How would you describe the place in the photo? Please choose maximum 3 words from the list below:

	Pick a maximum 3 descriptors (1)

1: green (53)	
2: urban (54)	
3: historic (55)	
4: natural (56)	
5: old (57)	
6: modern (58)	
7: new (59)	
8: attractive (60)	
9: cultural (61)	
10: built (62)	

End of Block: Descriptors2

Start of Block: Descriptors1

How would you describe the place in the photo? Please choose maximum 3 words from the list below:

	Pick a maximum 3 descriptors (1)
1: green (53)	
2: urban (54)	
3: historic (55)	
4: natural (56)	
5: old (57)	
6: modern (58)	
7: new (59)	
8: attractive (60)	
9: cultural (61)	
10: built (62)	

End of Block: Descriptors1

Start of Block: Descriptors4.1

How would you describe the place in the photo? Please choose maximum 3 words from the list below:

	Pick a maximum 3 descriptors (1)

1: green (53)	
2: urban (54)	
3: historic (55)	
4: natural (56)	
5: old (57)	
6: modern (58)	
7: new (59)	
8: attractive (60)	
9: cultural (61)	
10: built (62)	

End of Block: Descriptors4.1

Start of Block: familiarity

Are you familiar with the places that were shown in the videos?

	I am very familiar (1)	I am familiar (2)	Not sure (3)	I am not familiar (4)	I am not familiar at all (5)
Image:Screenshot 2019 10 18 at 10.58.45 (1)	☐	☐	☐	☐	☐
2 (2)	☐	☐	☐	☐	☐
3 (3)	☐	☐	☐	☐	☐
4 (4)	☐	☐	☐	☐	☐

End of Block: familiarity

Start of Block: Socio - dem

By moving the slider, indicate your preference for **green/natural** or **urban/built** environments.

Green No preference Urban/built environments environments

1 2 3 4 5

By moving the slider, indicate your preference for **modern** or **historic** environments.

Start of Block: Thank you

Thank you for taking part in this study!

Appendix 14. Chapter 4 publication additional content

Author contributions

Conceptualization, A.B., I.B. and C.A.; methodology, R.R., A.B., C.A. and I.B.; formal analysis, R.R., A.B., C.A. and I.B.; data curation, R.R.; writing—original draft preparation, R.R. and A.B.; writing—reviewing and editing, R.R., A.B., I.B. and C.A. All authors have read and agreed to the published version of the manuscript.

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Institutional review board statement

The study was conducted in accordance with the Declaration of Helsinki and approved by the Faculty Research Ethics Committee of The University of the West of England (UWE REC REF No.: HAS.19.08.005, date of approval: 1 October 2019).

Informed consent statement

Informed consent was obtained from all participants involved in the study. Written informed consent has been obtained from the participants to publish the paper.

Data availability statement

The data presented in this study are available on request from the corresponding author.

Acknowledgements

We would like to thank Alice Stephenson and UWE Psychology technicians: Janet Watkins and Hardeep Adams.

Conflicts of interest

The authors declare no conflict of interest.

Appendix 15. Chapter 5 extended methods

Study design

Unlike the previous pilot study (Chapter 4), this experiment utilised a between subjects design. A primary focus of this study was to compare the use of flat-screen as an exposure method with VR. Participants were assigned to one of the two groups: flat-screen or VR. Group assignment was random so that comparisons could be made between experimental conditions (Charness et al., 2012). In this study, between subjects was suitable so to compare groups and isolate the effect of technology (flat-screen or VR). This study was fairly involved due to the use of EEG and the VR HMD simultaneously which then meant the study was long in duration. The study was also conducted under stricter regulations relating to Covid transmission and so the duration of the study was a concern. Having a between subjects design resulted in participants in only needing to take part in one condition of the study (flat-screen or VR) and therefore reducing their time in the laboratory. A challenge for between subjects designs is that they require larger sample sizes, however, as this study was an exploratory pilot study, this was less significant.

Data analysis

Similar to the previous pilot study (Chapter 4), this experiment also used linear mixed models for analysis of the subjective data. More detail of this analysis technique is outlined in [Appendix 9](#).

This study also used EEG as a physiological measure and adopted spectral analysis in order to analyse the EEG data as frequency data. This technique is also previously described in the extended methods of Chapter 4 ([Appendix 9](#)).

Stimuli

It should be noted that the environments shown as stimuli in this study varied in the amount of people that could be seen in the environment. There were some people visible at the end of the video of the historic environment but no people were in the green or blue environment. This could be a limitation of the study in that the effect of seeing people may have had a confounding effect on the results. Few studies to date have looked at the impact of people being present in restorative environments, and this will be investigated further in the next study in this thesis (Chapter 6).

Furthermore, in relation to the stimuli, several criteria needed to be met when choosing a

VR HMD for the study. The headset needed to provide sufficient differentiation from the flat-screen alternative, provide a consistent and reliable experience, comply with the covid regulations which were in place at the time, and be available and affordable. The decision was therefore made to use the Oculus Go (Meta Reality Labs, 2018) which addressed these criteria, in addition to being lightweight and comfortable, and a standalone device. The headset required for this study only needed to be able to show the VR environments, which were pre-filmed videos rather than computer-generated spaces, which may have required a higher specification headset. In the experiment in Chapter 6, the Meta Quest 2 is used as a newer model with improved specifications necessary for the environments which were created and shown through the HMD.

Measures

Compared to the previous pilot study (Chapter 4), an additional outcome measure was added in which was for anxiety (STAI; Marteau & Bekker, 1992). The STAI was added in as another measure which has the advantage of differentiating between state and trait and having frequently used in previous studies (Song et al., 2020; Yao et al., 2021; Yin et al., 2020). This was measured as an outcome alongside more general mental well-being (UWIST MACI; Matthews et al., 1990).

Covid restrictions

When this study was conducted, there were strict Covid regulations and precautions in place which presented significant challenges for running this face-to-face experiment, as well as it may have had an effect on the observed effect sizes in this study. In addition to a usual risk assessment being needed to conduct research, another risk assessment specific to reducing the risk and transmission of Covid to the researcher and participants was necessary. This resulted in delays to the study's data collection in that sign-ups to the study were slow as there were few people around on university campus (most activities/teaching resorted to online alternatives).

Extra precautioning measures were brought into place in order for the study to be conducted safely. Firstly, as the researcher I was required to wear personal protective equipment when conducting data collection and being face-to-face with participants. This involved wearing a disposable apron, face mask and visor and replacing after every participant. Participants were also required to wear a face mask at all times during the study. Additionally, an extensive cleaning routine was put in place as well as protective coverings placed on the VR HMD which were also replaced between participants. Both researcher and

participants were required to conduct a flow test prior to the experiment and only proceeded if both were negative.

Appendix 16. Chapter 5 ethical approval



Faculty of Health & Applied

Sciences

Glenside Campus

Blackberry Hill

Stapleton

Bristol BS16 1DD

Tel: 0117 328 1170

UWE REC REF No: HAS.21.03.124

7th May 2021

Issy Bray

Dear Issy

Application title: Mental wellbeing and exposure to restorative environments: comparing flatscreen with immersive virtual reality (IVR) simulations

Thank you for responding to the conditions raised in my letter to you of 29th April 2021.

I can now confirm full ethics approval for your project, but please note the proviso below.

Please note: In light of the current situation regarding COVID-19, we can only authorise an immediate start for activities that do not breach either national laws or University policies (for further information please click on the following link

<https://intranet.uwe.ac.uk/taskshttps://eur01.safelinks.protection.outlook.com/?url=https://intranet.uwe.ac.uk/tasks-guides/Guide/research-and-enterprise-covid-19information%23part1&data=02|01|Leigh.Taylor@uwe.ac.uk|e25d84c447a14c40bf1708d8660fac68|07ef1208413c4b5e9cdd64ef305754f0|0|0|637371564795692129&sdata=elRMUjXjd38RfroyjsYvq8k0yO3VstVwKWcro9fslcg=&reserved=0guides/Guide/researchand-enterprise-covid-19-information#part1>). In these uncertain times, law and policy may change swiftly and frequently.

We are, however, continuing to scrutinise and grant ethical approval for activities that cannot take place at present, to ensure that once the situation changes and activities can go ahead, the research is not unnecessarily delayed.

What this means for your application:

1. If your application DOES NOT involve activities affected by the current crisis (e.g. online surveys or telephone interviews etc.) then you may start your research as soon as you receive this formal notification of your ethical approval;
2. If your application DOES involve activities affected by the current crisis then you must not start your research until you are lawfully and safely able to do so, and when it does not breach the University's policies. This will affect the dates you have supplied on your application form in relation to start and finish. When you have new dates, please can you write to us in order that we can add this information to your file?

The following standard conditions apply to all research given ethical approval by a UWE Research Ethics Committee:

1. You must notify the relevant UWE Research Ethics Committee in advance if you wish to make significant amendments to the original application: these include any changes to the study protocol which have an ethical dimension. Please note that any changes approved by an external research ethics committee must also be communicated to the relevant UWE committee.
2. You must notify the Research Ethics Sub-Committee (formerly UREC) if you terminate your research before completion.
3. You must notify the Research Ethics Sub-Committee if there are any serious events or developments in the research that have an ethical dimension.

Please note: The RESC is required to monitor and audit the ethical conduct of research involving human participants, data and tissue conducted by academic staff, students and researchers. Your project may be selected for audit from the research projects submitted to and approved by the RESC and its committees.

We wish you well with your research.

Yours sincerely

Dr Julie Woodley

Chair

Faculty Research Ethics Committee

Appendix 17. Chapter 5 consent form



Consent Form

Project title: Mental wellbeing and exposure to restorative environments: comparing flatscreen with immersive virtual reality (IVR) simulations. **Principal investigator:** Issy Bray

This consent form will have been given to you with the Participant Information Sheet. Please ensure that you have read and understood the information contained in the Participant Information Sheet and asked any questions before you sign this form. If you have any questions please contact a member of the research team, whose details are set out on the Participant Information Sheet.

If you are happy to take part, please sign and date the form.

- I have read and understood the information in the Participant Information Sheet which I have been given to read before asked to sign this form;
- I have been given the opportunity to ask questions about the study;
- I have had my questions answered satisfactorily by the research team;
- I understand that EEG electrodes will be placed on my head to measure brain activity, and EDA electrodes my hands to measure other physiological activity (skin responses);
- I understand that I may be required to have a virtual reality headset placed on my head to watch a 360-degree environment video.
- I have checked that I meet the inclusion criteria and am not excluded by the exclusion criteria;
- I understand that I can ask questions about the study after I have completed the experiment;
- I understand that I am free to withdraw from the study at any time without having to give a reason for withdrawing;
- I understand that I am free to withdraw my data from any future analysis/or publication, provided that I inform the principal investigator within one week of the date from when this form is signed and without needing to give a reason;
- I understand that my data may be stored for up to 10-years and used in research publications, but my data will remain anonymous;
- I agree to take part in the research
- I understand the nature and purpose of the procedures involved communicated to me on a separate information sheet and in discussion with the researchers.
- I understand that a unique code will replace my name so that my data can remain confidential and that I will not be identified in any way when the research is published.
- I agree to the principal investigator recording and processing the data I provide during the course of the study unless I state otherwise. I understand that this information will be used only for the purpose set out in the information sheet, and my consent is conditional upon the University complying with its duties and obligations under the Data Protection Act.

I fully and freely consent to participate in a study entitled: Mental wellbeing and exposure to restorative environments: comparing flat-screen with immersive virtual reality (IVR) simulations.

Principal investigator: Issy Bray

Signature of participant:

Date: _____



Information Sheet

Project title: Mental wellbeing and exposure to restorative environments: comparing flatscreen with immersive virtual reality (IVR) simulations.

Principal investigator: Issy Bray

You are being invited to take part in a research study. Before you decide to take part it is important for you to understand why the research is being done and what it will involve. Please take time reading the following information carefully and discuss it with others if you wish. Please ask the principal investigator if anything is not clear or if you would like more information. Take time to decide whether you wish to take part.

What is the purpose of this research?

The purpose of the research is to compare the benefits of exposure to restorative environments when viewed on a flat-screen monitor versus immersive virtual reality (IVR) simulations. If we can identify whether new IVR technology is a beneficial method for exposure to restorative environments, important implications for populations with limited mobility will follow.

Why have I been asked and do I have to take part?

There are several inclusion and exclusion criteria. Please read through them carefully and consider whether you are eligible to take part in this study.

Persons eligible to take part:

- Healthy volunteers
- Normal or corrected-to-normal vision

Persons not eligible to take part:

- Suffer from skin allergy or hypersensitive skin (you may react to the electrodes or electrolyte)
- Have experienced an epileptic seizure within the past 12-months
- Have current or previous hypertension, anxiety, psychiatric, or neurological disorders, or current illness (e.g. influenza, coronavirus)
- Taking prescribed medication for brain or psychiatric conditions (e.g. anxiety, depression or epilepsy)

It is up to you to decide whether to take part. If you do decide to take part, you will be given this information sheet to keep and be asked to sign a consent form. If you decide to take part, you are still free to withdraw at any time (up to a week after taking part) without giving a reason.

Psychology students who participate will be eligible to receive a 2 course credits for completing the study, in keeping with standard practice for psychology undergraduate course participation. Psychology students have the choice of many studies to participate in, and so do not have to take part in this study if they do not wish to. Psychology students will still be eligible to receive the course credit if they decide to withdraw at any time during the study.

How will the research be done and what will I have to do?

If you do decide to take part, we will ask you to come into the laboratory on one occasion for approximately two hours. Before you come in, the researcher will contact you to check that you do not have any Covid-19 symptoms and that you have had a negative lateral flow test within the last week. Current UWE guidance in relation to Covid-19 will be followed at all times

(<https://www.uwe.ac.uk/news/coronavirus/returning-to-campus>).

When you first arrive, the procedure will be explained, and you will be asked to confirm that you are happy to proceed and feeling well on the day.

If you are happy to continue, the physiological recording equipment will be set up. Please note that all equipment used and hard surfaces in the laboratory will be cleaned between participants in line with current guidance. These processes are described in more detail in the risk assessment for this study, which is available on request. We are also happy to answer any questions you might have about the Covid-prevention measures in place.

Set up of physiological recording equipment

We are interested in measuring brain activity (electroencephalography; EEG) and physiological responses (electrodermal activity; EDA). Measuring brain and body physiology is of great interest to many researchers. Directly measuring the body and brain in real time without requiring behavioural responses can provide us with insights into cognitive functioning, such as perception, attention, and language processing. EEG and associated physiological measurements are very commonly performed and are routinely used in research and clinical assessments in the NHS. They have been used safely for many decades. All equipment comes from certified suppliers, who are obliged by law to adhere to published guidelines on electrical and mechanical safety. The equipment is checked regularly for electrical safety.

Using EEG equipment, we will measure the electrical activity of your brain. EEG measures the electrical voltage signals of brain activity directly from sensors that touch the scalp. Sensor placement and preparation typically requires 45 minutes. A snug fitting cap made of an elasticated cloth material containing sensors, will be placed on your head. Next, a gel that contains salt will be placed between each sensor and the scalp. This provides a better signal of the brain activity. The procedure doesn't cause pain or harm, but it may feel a little unusual as you are wearing a snug fitting cap – like a swimming cap.

If you do feel any discomfort at any time, please let the researcher know and the study can be stopped at any time.

Using the BIOPAC equipment, we will measure EDA. The procedure entails wearing hand equipment including stick-on electrodes and this doesn't cause pain, but if you do feel any discomfort at any time, please let the researcher know and the study can be stopped at any time.

Immersive virtual reality (VR) technology

You may be required to wear a virtual reality head-mounted display whilst sitting down on a chair to watch the videos. Sometimes, a side effect of using a VR headset is the feeling of motion sickness. If you do feel motion sick or dizzy at any point, you can alert us and the headset will be removed immediately, and water will be readily available.

Tasks

Once the equipment is set up, the experiment will begin, and you will be asked to complete a questionnaire that includes several videos. Continual recordings of your physiological signals will be recorded while you are watching the videos. The videos last ~18 minutes in total and you will be asked to complete rating scales between videos, but you will be able to take breaks between the different sequences.

At the end

Once the task finishes the equipment will be removed. You are able to wash your hair (please bring your own towel). There may be some slight discomfort when the electrodes are removed from your skin – similar to removing a sticking plaster – and some people may develop a mild transitory rash where the electrodes were attached, but this usually disappears within minutes.

Is this information confidential and held securely, and what will be done with the results?

All data which leaves the laboratory will have your name removed and will be anonymised so that you cannot be recognised from it. Only the recruiting researcher will have access to your name in the first instance, and you will not be personally identified in any report, thesis, or publication of results. All information is confidential.

All anonymised data will be held for as long as it retains research value although this will not exceed 10-years. The anonymised data may be made available for further appropriately approved research through the University. No data will be published in a way that could identify individual participants.

If you wish to obtain a copy of the summary results once they are available, please contact the principal investigator.

What happens if I have a complaint?

If something goes wrong, and consequently leads to a complaint, the Project Principal Investigator will be informed.

Do you have any further questions?

If you feel upset as a result of participating in the study, please consider using the support information below, as well as advising the researchers.

If you have questions about the research - either now or at some future date - please contact the researchers.

Contact details:

Recruiting researcher: Rebecca Reece

Email: Rebecca.Reece@uwe.ac.uk

Principal investigator: Issy Bray

Email: Issy.Bray@uwe.ac.uk

Co-investigators: Nigel Newbutt (Nigel.Newbutt@uwe.ac.uk), Chris Alford (Chris.Alford@uwe.ac.uk), David Satenstein (David.Satenstein@uwe.ac.uk)

Support

UWE Wellbeing Service

Telephone: 0117 32 86268

Email: wellbeing@uwe.ac.uk

Bristol Mind

Telephone: 0117 98 23209

<http://www.bristolmentalhealth.org/services/wellbeing-therapy-services/>

Privacy Notice



Purpose of the Privacy Notice

This privacy notice explains how the University of the West of England, Bristol (UWE) collects, manages and uses your personal data before, during and after you participate in *“Mental wellbeing and exposure to restorative environments: comparing flat-screen with immersive virtual reality (IVR) simulations”*. ‘Personal data’ means any information relating to an identified or identifiable natural person (the data subject). An ‘identifiable natural person’ is one who can be identified, directly or indirectly, including by reference to an identifier such as a name, an identification number, location data, an online identifier, or to one or more factors specific to the physical, physiological, genetic, mental, economic, cultural or social identity of that natural person.

This privacy notice adheres to the General Data Protection Regulation (GDPR) principle of transparency. This means it gives information about:

- How and why your data will be used for the research;
- What your rights are under GDPR; and
- How to contact UWE Bristol and the project lead in relation to questions, concerns or exercising your rights regarding the use of your personal data.

This Privacy Notice should be read in conjunction with the Participant Information Sheet and Consent Form provided to you before you agree to take part in the research. **Why are we processing your personal data?**

UWE Bristol undertakes research under its public function to provide research for the benefit of society. As a data controller we are committed to protecting the privacy and security of your personal data in accordance with the (EU) 2016/679 the General Data Protection Regulation (GDPR), the Data Protection Act 2018 (or any successor legislation) and any other legislation directly relating to privacy laws that apply (together “the Data Protection Legislation”). General information on Data Protection law is available from the Information Commissioner’s Office (<https://ico.org.uk/>). **How do we use your personal data?**

We use your personal data for research with appropriate safeguards in place on the lawful bases of fulfilling tasks in the public interest, and for archiving purposes in the public interest, for scientific or historical research purposes.

We will always tell you about the information we wish to collect from you and how we will use it.

We will not use your personal data for automated decision making about you or for profiling purposes.

Our research is governed by robust policies and procedures and, where human participants are involved, is subject to ethical approval from either UWE Bristol’s Faculty or University Research Ethics Committees. This research has been approved by the Faculty of Health and Applied Sciences Research Ethics Committee. The research team adhere to the Ethical guidelines of the British Educational Research Association (and/or the principles of the Declaration of Helsinki, 2013) and the principles of the General Data Protection Regulation (GDPR).

For more information about UWE Bristol’s research ethics approval process please see our Research Ethics webpages at: www1.uwe.ac.uk/research/researchethics

What data do we collect?

The data we collect will vary from project to project. Researchers will only collect data that is essential for their project. The specific categories of personal data processed are described in the Participant Information Sheet provided to you with this Privacy Notice **Who do we share your data with?**

We will only share your personal data in accordance with the attached Participant Information Sheet and your Consent.

How do we keep your data secure?

We take a robust approach to protecting your information with secure electronic and physical storage areas for research data with controlled access. If you are participating in a particularly sensitive project UWE Bristol puts into place additional layers of security. UWE Bristol has Cyber Essentials information security certification.

Alongside these technical measures there are comprehensive and effective policies and processes in place to ensure that users and administrators of information are aware of their obligations and responsibilities for the data they have access to. By default, people are only granted access to the information they require to perform their duties. Mandatory data protection and information security training is provided to staff and expert advice available if needed.

How long do we keep your data for?

Your personal data will only be retained for as long as is necessary to fulfil the cited purpose of the research. The length of time we keep your personal data will depend on several factors including the significance of the data, funder requirements, and the nature of the study. Specific details are provided in the attached Participant Information Sheet.

Anonymised data that falls outside the scope of data protection legislation as it contains no identifying or identifiable information may be stored in UWE Bristol's research data archive or another carefully selected appropriate data archive. **Your Rights and how to exercise them**

Under the Data Protection legislation you have the following **qualified** rights:

- (15) The right to access your personal data held by or on behalf of the University;
- (16) The right to rectification if the information is inaccurate or incomplete;
- (17) The right to restrict processing and/or erasure of your personal data;
- (18) The right to data portability;
- (19) The right to object to processing;
- (20) The right to object to automated decision making and profiling;
- (21) The right to [complain](#) to the Information Commissioner's Office (ICO).

Please note, however, that some of these rights do not apply when the data is being used for research purposes if appropriate safeguards have been put in place.

We will always respond to concerns or queries you may have. If you wish to exercise your rights or have any other general data protection queries, please contact UWE Bristol's Data Protection Officer (dataprotection@uwe.ac.uk).

If you have any complaints or queries relating to the research in which you are taking part please contact either the research project lead, whose details are in the attached Participant Information Sheet, UWE Bristol's Research Ethics Committees (research.ethics@uwe.ac.uk) or UWE Bristol's research governance manager (Ros.Rouse@uwe.ac.uk)

Appendix 19. Chapter 5 questionnaire

Start of Block: Introduction

Introduction

You are being invited to take part in a research study exploring the experience of exposure to different restorative environments. You will be required to watch a series of videos (either on a flat-screen computer or using VR) and answer some questions. Participation is entirely voluntary and anonymous. You will be awarded 2 psychology participation credits in exchange of your participation. The experiment will take a maximum of 2 hours, including the time to set up the EEG. The total length of the videos you will watch is ~18 minutes. You are free to take a break and have a drink after each video/question sequence before moving onto the next. You can withdraw at any time with no consequences and without providing a reason. You can withdraw your data by contacting the research team within one week from today. By clicking the Next button you are confirming your consent to the use of data. Full information can be found on the information sheet. If you have any questions please ask the researcher.

End of Block: Introduction

Start of Block: Block 1

Pseudonym

Please now enter your participant code.

End of Block: Block 1

Start of Block: Block 14

Please answer some questions about how you feel generally.

A number of statements which people have used to describe themselves are given below. Read each statement on the left hand side and in each case click the 'slider' to move it and place it underneath the word(s) at the top to indicate how you *generally* feel. **There are no right or wrong answers.** Do not spend too much time on any one statement but give the answer which seems to describe how you generally feel.

Once you have answered all of the slider questions, please click the arrow at the bottom right hand side to proceed to the rest of the experiment.

	Almost	Sometimes	Often	Almost never	always
	1	2	3	4	
I am "cool, calm and collected" ()					

I worry too much over something that really doesn't matter ()	
I feel secure ()	
I get in a state of tension or turmoil as I think over my recent concerns and interests ()	
I feel nervous and restless ()	
I make decisions easily ()	

End of Block: Block 14

Start of Block: Block 2

Traffic video 1 Please watch the first video before continuing.

End of Block: Block 2

Start of Block: Block 3

Mood traffic 1 How do you feel now?

In each case move the 'slide' underneath the word at the top that best explains how you feel about each of the emotions in the list on the left had side.

	Definitely not	Not much	Quite	Definitely
	1	2	3	4
Relaxed ()				
Happy ()				
Sad ()				
Nervous ()				

Read each statement on the left hand side and in each case click the ‘slider’ to move it and place it underneath the word at the top to indicate how you feel *right now*, that is, at this moment. **There are no right or wrong answers.** Do not spend too much time on any one statement but give the answer which seems to describe your present feelings best.

Once you have answered all of the slider questions, please click the arrow at the bottom right hand side to proceed to the rest of the experiment.

	Not at all	Somewhat	Moderately	Very much
			so	so
	1	2	3	4
I feel calm ()				
I am tense ()				
I feel at ease ()				
I feel nervous ()				
I feel relaxed ()				
I am worried ()				

End of Block: Block 3

Start of Block: Block 12

Enviro video 1

Please watch the next video before continuing. **Imagine you are taking a walk** in the environment during the daytime.

End of Block: Block 12

Start of Block: Block 4

Mood enviro 1

How do you feel now?

In each case move the ‘slide’ underneath the word at the top that best explains how you feel about each of the emotions in the list on the left had side.

Definitely Not much Quite Definitely

	not	
	1	2 3 4
Relaxed ()		
Happy ()		
Sad ()		
Nervous ()		

Read each statement on the left hand side and in each case click the 'slider' to move it and place it underneath the word at the top to indicate how you feel *right now*, that is, at this moment. **There are no right or wrong answers.** Do not spend too much time on any one statement but give the answer which seems to describe your present feelings best.

Once you have answered all of the slider questions, please click the arrow at the bottom right hand side to proceed to the rest of the experiment.

	Not at all	Somewhat	Moderately	Very much
		so		so
	1	2	3	4
I feel calm ()				
I am tense ()				
I feel at ease ()				
I feel nervous ()				
I feel relaxed ()				
I am worried ()				

Are you familiar with the area depicted by the video?

Please choose a statement from the list below.

- ☐ I know the area well (1) ☐ I know
the area a bit (2)
- ☐ I don't know the area (3)

End of Block: Block 4

Start of Block: Block 5

Traffic 2

Please watch the next video before continuing.

End of Block: Block 5

Start of Block: Block 15

How do you feel now?

In each case move the 'slide' underneath the word at the top that best explains how you feel about each of the emotions in the list on the left hand side.

	Definitely not	Not much	Quite	Definitely
	1	2	3	4
Relaxed ()				
Happy ()				
Sad ()				
Nervous ()				

Read each statement on the left hand side and in each case click the 'slider' to move it and place it underneath the word at the top to indicate how you feel *right now*, that is, at this moment. **There are no right or wrong answers.** Do not spend too much time on any one statement but give the answer which seems to describe your present feelings best.

Once you have answered all of the slider questions, please click the arrow at the bottom right hand side to proceed to the rest of the experiment.

	Not at all	Somewhat	Moderately	Very much
			so	so
	1	2	3	4
I feel calm ()				
I am tense ()				
I feel at ease ()				
I feel nervous ()				
I feel relaxed ()				
I am worried ()				

End of Block: Block 15

Start of Block: Block 6

Enviro video 2

Please watch the next video before continuing. **Imagine you are taking a walk** in the environment during the daytime.

End of Block: Block 6

Start of Block: Block 7

Mood enviro 2

How do you feel now?

In each case move the 'slide' underneath the word at the top that best explains how you feel about each of the emotions in the list on the left had side.

	Definitely not	Not much	Quite	Definitely
	1	2	3	4
Relaxed ()				

Happy ()	
Sad ()	
Nervous ()	

Read each statement on the left hand side and in each case click the 'slider' to move it and place it underneath the word at the top to indicate how you feel *right now*, that is, at this moment. **There are no right or wrong answers.** Do not spend too much time on any one statement but give the answer which seems to describe your present feelings best.

Once you have answered all of the slider questions, please click the arrow at the bottom right hand side to proceed to the rest of the experiment.

	Not at all	Somewhat	Moderately	Very much
		so		so
	1	2	3	4
I feel calm ()				
I am tense ()				
I feel at ease ()				
I feel nervous ()				
I feel relaxed ()				
I am worried ()				

Are you familiar with the area depicted by the video?

Please choose a statement from the list below.

☐ I know the area well (1) ☐ I know

the area a bit (2) ☐ I don't know the area

(3)

End of Block: Block 7

Start of Block: Block 8

Traffic 3

Please watch the next video before continuing.

End of Block: Block 8

Start of Block: Block 17

How do you feel now?

In each case move the 'slide' underneath the word at the top that best explains how you feel about each of the emotions in the list on the left hand side.

	Definitely not	Not much	Quite	Definitely
	1	2	3	4
Relaxed ()				
Happy ()				
Sad ()				
Nervous ()				

Read each statement on the left hand side and in each case click the 'slider' to move it and place it underneath the word at the top to indicate how you feel *right now*, that is, at this moment. **There are no right or wrong answers.** Do not spend too much time on any one statement but give the answer which seems to describe your present feelings best.

Once you have answered all of the slider questions, please click the arrow at the bottom right hand side to proceed to the rest of the experiment.

	Not at all	Somewhat	Moderately	Very much
	1	2	3	4
I feel calm ()				
I am tense ()				

I feel at ease ()	
I feel nervous ()	
I feel relaxed ()	
I am worried ()	

End of Block: Block 17

Start of Block: Block 9

Enviro video 3

Please watch the next video before continuing. **Imagine you are taking a walk** in the environment during the daytime.

End of Block: Block 9

Start of Block: Block 10

Mood enviro 3

How do you feel now?

In each case move the 'slide' underneath the word at the top that best explains how you feel about each of the emotions in the list on the left hand side.

	Definitely not	Not much	Quite	Definitely
	1	2	3	4
Relaxed ()				
Happy ()				
Sad ()				
Nervous ()				

Read each statement on the left hand side and in each case click the 'slider' to move it and place it underneath the word at the top to indicate how you feel *right now*, that is, at this moment. **There are no right or wrong answers.** Do not spend too much time on any one statement but give the answer which seems to describe your present feelings best.

Once you have answered all of the slider questions, please click the arrow at the bottom right hand side to proceed to the rest of the experiment.

	Not at all	Somewhat	Moderately	Very much
		so	so	
	1	2	3	4
I feel calm ()				
I am tense ()				
I feel at ease ()				
I feel nervous ()				
I feel relaxed ()				
I am worried ()				

Are you familiar with the area depicted by the video?

Please choose a statement from the list below.

- ☐ I know the area well (1) ☐ I know
the area a bit (2) ☐ I don't know the area
(3)

End of Block: Block 10

Start of Block: Block 11

End

That is the end of the videos, thank you for watching.

Before finishing, please answer the next few questions.

End of Block: Block 11

Start of Block: Block 17 What is
your age?

What is your gender? ☐ Male (1)

☐ Female (2) ☐

Transgender (3) ☐ Prefer to

self-describe (4)

☐ Prefer not to say (5)

What is your ethnicity? ☐ Asian - Bangladeshi (1) ☐ Asian -

Indian (2) ☐ Asian - Pakistani (3) ☐ Asian - any other

Asian background (4) ☐ Black or Black British - African (5)

☐ Black or Black British - Caribbean (6) ☐ Black or

Black British - any other Black background (7) ☐ Mixed -

White and Asian (8) ☐ Mixed - White and Black African

(9) ☐ Mixed - White and Black Caribbean (10) ☐ Mixed

- any other mixed background (11) ☐ White - British (12)

☐ White - Irish (13) ☐ White - Other (14) ☐ Other

Ethnic Group - Chinese (15) ☐ Other Ethnic Groups - any

other ethnic group (16) ☐ Not stated (17)

End of Block: Block 17

Start of Block: Block 18

Using the slider, please state your preference for urban and natural environments.

Strong preference environments	Slight preference natural environments	No preference for natural	Slight preference for urban environments	Strong preference for urban environments

1	2	3	4	5

Preference ()



During your daily life, to what extent do you immerse yourself within environments just to appreciate and observe them? ☐ Very often (1) ☐ Often (2) ☐ Not sure (3) ☐

Sometimes (4)

☐ Never (5)

End of Block: Block 18

Start of Block: Qualitative questions

How was your experience of watching the videos? (optional)

Is there anything in particular that attracted your attention in the videos? (optional)

To what extent did you find the experience realistic? (optional)

To what extent did you feel immersed in the environment? (optional)

How relaxing/engaging was it watching the videos? If it was relaxing or engaging, why?
(optional)

Do you have any comments on the quality of the videos? Did you identify any technical issues? (optional)

Do you have any additional comments? (optional)

End of Block: Qualitative questions

Appendix 20. Chapter 5 publication additional content

Supplementary materials

The following supporting information can be downloaded at:

<https://www.mdpi.com/article/10.3390/ijerph19159457/s1> , Table S1: Mean theta activity;

Table S2: Mean alpha activity; Table S3: Mean beta activity; Table S4: Mean gamma activity.

Author contributions

Conceptualization, I.B., C.A., N.N. and A.B.; methodology, I.B., N.N., C.A., A.B. and R.R.; formal analysis, R.R., A.B., N.N. and C.A.; data curation, R.R. and A.B.; writing—original draft preparation, R.R. and A.B.; writing—review and editing, R.R., A.B., I.B., N.N., D.S. and C.A. All authors have read and agreed to the published version of the manuscript.

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Institutional review board statement

The study was conducted in accordance with the Declaration of Helsinki and approved by the Faculty Research Ethics Committee of The University of the West of England (UWE REC REF No.: HAS.21.03.124, date of approval: 7 May 2021).

Informed consent statement

Informed consent was obtained from all participants involved in the study. Written informed consent has been obtained from the participants to publish this paper.

Data availability statement

The data presented in this study are available on request from the corresponding author.

Acknowledgements

We would like to thank Tegan Negus, Alice Stephenson, and UWE Psychology technicians; Janet Watkins and Hardeep Adams.

Conflicts of interest

The authors declare no conflict of interest.

Appendix 21. Chapter 6 ethical approval



College of Health,
Science &
Society
Glenside Campus
Blackberry Hill
Stapleton
Bristol BS16 1DD

Tel: 0117 328
1170

UWE REC REF No: CHSS.23.11.065

12th January 2024

Rebecca Reece

Dear Rebecca

Project title: The presence of people and over-crowding in urban greenspaces: examining the impacts on social connectedness and restoration

I am writing to confirm that the Research Ethics Committee is satisfied that you have addressed all the conditions relating to our previous letter sent on 3rd January 2024 and that the project has now been given ethical approval to proceed until 1st January 2025.

The following standard conditions apply to all research given ethical approval by a UWE Research Ethics Committee:

1. You must notify the relevant UWE Research Ethics Committee in advance if you wish to make significant amendments to the original application: these include any changes to the study protocol which have an ethical dimension. Please note that any changes approved by an external research ethics committee must also be communicated to the relevant UWE committee.
2. You must notify the Research Ethics Committee if you terminate your research before completion.
3. You must notify the Research Ethics Committee if there are any serious events or developments in the research that have an ethical dimension.

Failure to fulfil these conditions may mean that approval is withdrawn.

Please ensure that before proceeding with your research:

- You have sought contractual advice from the UWE Contracts Team (megan.wiggins@uwe.ac.uk) if your research involves external funding and/or contracts with partner organisations;
- You have sought advice from the UWE Data Protection Team (dataprotection@uwe.ac.uk) if, in relation to collecting and/or sharing personal data, a third party (i.e. any person or institution extraneous to UWE) is involved in the research project.
- You have completed your UWE Research Data Management Plan.
- You have completed all necessary and sufficient risk assessments.

All applications for international travel must follow the university process with bookings to be made in liaison with the Finance Services team through the University's designated travel management company. Please see the guidance at <https://intranet.uwe.ac.uk/taskshttps://intranet.uwe.ac.uk/tasksguides/Guide/travelling-on-university-businessguides/Guide/travelling-on-universitybusiness>.

Please note: The UEIC (University Ethics and Integrity Committee) is required to monitor and audit the ethical conduct of research involving human participants, data and tissue conducted by academic staff, students and researchers. Your project may be selected for audit from the research projects submitted to and approved by the UEIC and its committees.

We wish you well with your research.

Yours sincerely

Dr Julie Woodley

Chair

Faculty Research Ethics Committee

c.c. Issy Bray

Appendix 22. Chapter 6 consent form



Economic
and Social
Research Council

Consent Form

Project title: The presence of people and over-crowding in urban greenspaces: examining the impacts on social connectedness and restoration. **Principal investigator:** Rebecca Reece

This consent form will have been given to you with the Participant Information Sheet. Please ensure that you have read and understood the information contained in the Participant Information Sheet and asked any questions before you sign this form. If you have any questions please contact a member of the research team, whose details are set out on the Participant Information Sheet.

- I have read and understood the information in the Participant Information Sheet which I have been given to read before asked to sign this form.
- I have been given the opportunity to ask questions about the study.
- I have had my questions answered satisfactorily by the research team.
- I understand that I will be audio-recorded, and the recording will be destroyed once the data has been transcribed for analysis.
- I understand that I can take a break in the experiment at any time.
- I understand that my participation is voluntary and that I am free to withdraw at any time without giving a reason.
- I understand that my data may be stored for up to 10-years and used in research publications, but my data will remain anonymous.
- I agree to take part in the research.
- I understand that a unique code will replace my name so that my data can remain confidential and that I will not be identified in any way when the research is published.
- I agree to the principal investigator recording and processing the data I provide during the study unless I state otherwise. I understand that this information will be used only for the purpose set out in the information sheet, and my consent is conditional upon the University complying with its duties and obligations under the Data Protection Act.

I fully and freely consent to participate in a study entitled: The presence of people and over-crowding in urban greenspaces: examining the impacts on social connectedness and restoration.

Signature of participant: _____

Date: _____



Participant Information Sheet



Project title: The presence of people and over-crowding in urban greenspaces: examining the impacts on social connectedness and restoration.

Lead researcher: Rebecca Reece

You are invited to take part in research taking part at the University of the West of England, Bristol. It is funded by the Economic and Social Research Council (ESRC), through the South West Doctoral Training Partnership (SWDTP). Before you decide, it is important for you to understand why the research is being done and what it will involve. Please read this information sheet carefully. If you have any questions or would like more information please contact Rebecca Reece, University of the West of England, Bristol [Rebecca.Reece@uwe.ac.uk]. Please take time to decide whether you wish to take part.

Who is organising and funding the research?

The lead researcher for this project is Rebecca Reece. This project is part of an SWDTP PhD funded by the ESRC. Supervisors for this project are Dr Issy Bray (Director of Studies) (Issy.Bray@uwe.ac.uk) and Dr Lewis Elliott (L.R.Elliott@exeter.ac.uk).

What is the aim of the research?

The aim of the research is to investigate the impact of people being present in an urban greenspace on feelings of well-being, social connectedness, and restoration. A broad range of literature has shown the benefits that urban greenspace exposure can have on different facets of well-being, however limited research has looked at the influence of these spaces when there are other people using them at the same time. Additionally, we are interested in understanding whether age is an important factor. For this study, we are recruiting 62 participants in total across two age groups (18-24 yrs and 25 yrs+) and will be comparing the groups when analysing the data.

The results of our study will be analysed and included in the lead researcher's PhD thesis. The anonymised results may be presented at conferences and included in peer-reviewed research papers. As the results will be anonymous, no information will be able to be linked to the people who took part.

Why have I been invited to take part?

There are several inclusion and exclusion criteria. Please read through them carefully and consider whether you are eligible to take part in this study.

Persons eligible to take part:

- Adult 18 + years old.
- Normal or corrected-to-normal vision.

Persons **not** eligible to take part:

- Suffers from a chronic disease of the heart (e.g., pacemaker).
- Has high blood pressure.
- Suffers from severe motion sickness.

Do I have to take part?

You do not have to take part. It is up to you whether or not you want to be involved. If you do decide to take part, you will be given a copy of this information sheet to keep. You will also be asked to provide consent before taking part. If you decide to take part, you can withdraw from the research without giving a reason. You can withdraw your data up to 1 week from the date you participated and provided consent. If you want to withdraw from the study within this time, please email Rebecca Reece (Rebecca.Reece@uwe.ac.uk). There is no penalty if you do not want to take part or want to withdraw from the study.

What will happen to me if I take part and what do I have to do?

If you do decide to take part, we will ask you to take part on one occasion for approximately 1 hour. When you first arrive, the procedure will be explained, and you will be asked to confirm that you are happy to proceed and that you are feeling well on the day.

Once consent has been provided, the experiment will begin and you will first be asked to complete a questionnaire which also involves viewing several environments through a virtual reality head-mounted display (VR HMD). In between viewing each environment, you will be asked to complete several questionnaires regarding the environment you have just viewed. At the beginning of the study and after viewing each environment, we would like to measure your physiological stress response. To do this, your blood pressure and heart rate will be recorded using a BP/HR monitor worn on your wrist. If at the beginning of the study (at rest) you have high blood pressure then you will be advised to contact your GP and unfortunately you will not be eligible to take part in the rest of the study.

Time spent viewing the VR environments will total 30 mins (5 mins segments at a time). You are able to take breaks in between each VR segment. Once you have viewed all VR environments, you will be asked to take part in a brief ~10 mins interview with the researcher about the environments you have just viewed. This will complete the experiment.

What are the benefits of taking part?

The information you provide will give us a better understanding of how urban greenspaces are perceived depending on how many other people are present in the environment. By knowing this, it can also help us to design better urban greenspaces.

Additionally, if you decide to take part and as a thank you, you will receive a £10 voucher.

What are the possible risks of taking part?

You will be required to wear a virtual reality head-mounted display (VR HMD) whilst sitting down on a chair to watch the videos. Sometimes, a side effect of using a VR headset is the feeling of motion sickness. If you do feel motion sick or dizzy at any point, you can alert us and the headset will be removed immediately and you will be able to have a drink of water. You are free to take a break at any point during the experiment, just let the researcher know. If you need any support during or after the experiment, the researcher will put you in touch with suitable support. The research team are experienced in conducting experiments and are sensitive to the subject area. **What will happen to your information?**

All information we receive from you will be treated in the strictest confidence. Only the lead researcher will have access to your name in the first instance. You will not be personally identified in any report, thesis, or publication of results. All information is confidential. Your survey responses, interview recording, and transcription will be anonymised. This will be so that you cannot be recognised from it. Voice recordings will be destroyed securely immediately after anonymised transcription into a written record. Your anonymised data will be analysed together with other participants' data. We will make sure there is no chance of identification or re-identification after this point.

All anonymised data will be held for as long as it has research value. This will not exceed 10 years. Anonymised data will be stored on UWE OneDrive. Only the lead researcher and supervisors will have access. This is in line with the University's requirements and the Data Protection Act 2018 and General Data Protection Regulation requirements.

Where will the results of the research study be published?

A report will be written containing our research findings. This report will be included in the lead researcher's PhD thesis. The project funder is the ESRC.

A copy of the report will be available to all participants if you would like to see it. Key findings will also be shared both within and outside UWE. Anonymous and nonidentifying quotes may be used in publications and presentations. No data will be published that could identify individual participants.

Who has ethically approved this research?

The project has been reviewed and approved by the Faculty Research Ethics Committee (FREC) at UWE, Bristol. Any comments, questions or complaints about the ethical conduct of this study can be addressed to the Research Ethics Committee at the University of the West of England at:

Researchethics@uwe.ac.uk

What if something goes wrong?

If something goes wrong, and then leads to a complaint, the Director of Studies will be informed.

This study will involve answering questions about mental health and well-being. If you feel any discomfort at any time, please let the researcher know and the study can be stopped at any time. Please also consider using the support information provided below.

What if I have more questions or do not understand something?

If you would like any further information about the research, please contact:

Lead researcher: Rebecca Reece

Email: Rebecca.Reece@uwe.ac.uk

Support

UWE Wellbeing Service

Telephone: 0117 32 86268

Email: wellbeing@uwe.ac.uk

Bristol Mind

Telephone: 0117 203 4419 (Mindline) or 0117 980 0370

Website: <https://bristolmind.org.uk>

Thank you for volunteering for this study.

You will be given a copy of this Participant Information Sheet to keep.

Privacy Notice for Research Participants

Project title: The presence of people and over-crowding in urban greenspaces: examining the impacts on social connectedness and restoration.

Purpose of the Privacy Notice

This privacy notice explains how the University of the West of England, Bristol (UWE Bristol) collects, manages and uses your personal data before, during and after you participate in *'The presence of people and over-crowding in urban greenspaces: examining the impacts on social connectedness and restoration'*. 'Personal data' means any information relating to an identified or identifiable natural person (the data subject). An 'identifiable natural person' is one who can be identified, directly or indirectly. This can include by reference to an identifier such as a name, an identification number, location data, an online identifier. Or this can include to one or more factors specific to the physical, physiological, genetic, mental, economic, cultural or social identity of that natural person.

This privacy notice adheres to the General Data Protection Regulation (GDPR) principle of transparency. This means it gives information about:

- How and why your data will be used for the research;
- What your rights are under GDPR; and
- How to contact UWE Bristol and the project lead in relation to questions, concerns or exercising your rights regarding the use of your personal data.

This Privacy Notice should be read in conjunction with the Participant Information Sheet and Consent Form. These are provided to you before you agree to take part in the research. **Why are we processing your personal data?**

UWE Bristol undertakes research as a public organisation to provide research for the benefit of society. As a data controller, we are committed to protecting the privacy and security of your personal data. This is in accordance with the (EU) 2016/679 the General Data Protection Regulation (GDPR), the Data Protection Act 2018 (or any successor legislation) and any other legislation directly relating to privacy laws that apply (together “the Data Protection Legislation”). General information on Data Protection law is available from the Information Commissioner’s Office (<https://ico.org.uk/>). **How do we use your personal data?**

We use your personal data for research with appropriate safeguards in place on the lawful bases of fulfilling tasks in the public interest. And for archiving purposes in the public interest, for scientific or historical research purposes.

We will always tell you about the information we wish to collect from you and how we will use it. We will not use your personal data for automated decision making about you or for profiling purposes.

Our research is governed by robust policies and procedures. Where human participants are involved, is subject to ethical approval from either UWE Bristol’s Faculty or University Research Ethics Committees. This research has been approved by the Faculty of Health and Applied Sciences Research Ethics Committee. The research team adhere to the Ethical guidelines of the British Educational Research Association (and/or the principles of the Declaration of Helsinki, 2013) and the principles of the General Data Protection Regulation (GDPR).

For more information about UWE Bristol’s research ethics approval process please see our Research Ethics webpages at: www1.uwe.ac.uk/research/researchethics **What**

data do we collect?

The data we collect will vary from project to project. Researchers will only collect data that is essential for their project. The specific categories of personal data processed are described in the Participant Information Sheet provided to you with this Privacy Notice.

Who do we share your data with?

We will only share your personal data in accordance with the attached Participant Information Sheet and your Consent.

How do we keep your data secure?

We take a robust approach to protecting your information. This includes secure electronic and physical storage areas for research data with controlled access. If you are participating in a particularly sensitive project, UWE Bristol puts into place additional layers of security. UWE Bristol has Cyber Essentials information security certification.

Alongside these technical measures there are comprehensive and effective policies and processes in place. These are to make sure that users and administrators of information are aware of their obligations and responsibilities for the data they have access to.

By default, people are only granted access to the information they require to perform their duties. Mandatory data protection and information security training is provided to staff. Expert advice is available if needed.

How long do we keep your data for?

Your personal data will only be retained for as long as is necessary, to fulfil the cited purpose of the research. The length of time we keep your personal data will depend on several things. These include the significance of the data, funder requirements, and the nature of the study. Specific details are provided in the Participant Information Sheet.

Anonymised data that falls outside the scope of data protection legislation as it contains no identifying or identifiable information may be stored in UWE Bristol's research data archive or another carefully selected appropriate data archive. **Your Rights and how to exercise them**

Under the Data Protection legislation, you have the following **qualified** rights:

- (22) The right to access your personal data held by or on behalf of the University;
- (23) The right to rectification if the information is inaccurate or incomplete;
- (24) The right to restrict processing and/or erasure of your personal data;
- (25) The right to data portability;
- (26) The right to object to processing;
- (27) The right to object to automated decision making and profiling; (28) The right to [complain](#) to the Information Commissioner's Office (ICO).

We will always respond to concerns or queries you may have. If you wish to exercise your rights or have any other general data protection queries, please contact UWE Bristol's Data Protection Officer (dataprotection@uwe.ac.uk).

If you have any complaints or queries relating to the research in which you are taking part please contact either the research project lead, whose details are in the attached Participant Information Sheet or UWE Bristol's research governance manager (researchgovernance@uwe.ac.uk).

Appendix 24. Chapter 6 questionnaire

Start of Block: Block 16

Q32 Please enter your participant number.

End of Block: Block 16

Start of Block: Block 17

Q33 Have you ever used/experienced virtual reality (VR) before? ☐

Yes (1)

☐ No (2)

End of Block: Block 17

Start of Block: Baseline questions

Well-being/Stress Using the scale below, please indicate in terms of the way you generally feel.

	Definitely not (1)	Not much (2)	Quite (3)	Definitely (4)
Nervous (1)	☐	☐	☐	☐
Tense (2)	☐	☐	☐	☐
Relaxed (3)	☐	☐	☐	☐
Calm (4)	☐	☐	☐	☐
Happy (5)	☐	☐	☐	☐
Content (6)	☐	☐	☐	☐
Sad (7)	☐	☐	☐	☐
Sorry (8)	☐	☐	☐	☐
Active (9)	☐	☐	☐	☐
Energetic (10)	☐	☐	☐	☐
Passive (11)	☐	☐	☐	☐
Sluggish (12)	☐	☐	☐	☐

Loneliness UCLA Please indicate how often each of the statements below is descriptive of you.

	Never (1)	Rarely (2)	Sometimes (3)	Often (4)
I feel in tune with the people around me (1)	☐	☐	☐	☐
I lack companionship (2)	☐	☐	☐	☐
There is no one I can turn to (3)	☐	☐	☐	☐
I do not feel alone (4)	☐	☐	☐	☐
I feel part of a group of friends (5)	☐	☐	☐	☐
I have a lot in common with the people around me (6)	☐	☐	☐	☐
I am no longer close to anyone (7)	☐	☐	☐	☐
My interests and ideas are not shared by those around me (8)	☐	☐	☐	☐
I am an outgoing person (9)	☐	☐	☐	☐
There are people I feel close to (10)	☐	☐	☐	☐
I feel left out (11)	☐	☐	☐	☐
My social relationships are superficial (12)	☐	☐	☐	☐
No one really knows me well (13)	☐	☐	☐	☐
I feel isolated from others (14)	☐	☐	☐	☐
I can find companionship when I want it (15)	☐	☐	☐	☐
There are people who really understand me (16)	☐	☐	☐	☐
I am unhappy being so withdrawn (17)	☐	☐	☐	☐

People are around me but
not with me (18)

There are people I can talk
to (19)

There are people I can turn
to (20)

Trait Social Please rate the degree to which you agree or disagree with each statement using the following scale (1 = strongly disagree, 6 = strongly agree).

	Strongly disagree (1)	Disagree (2)	Slightly disagree (3)	Slightly agree (4)	Agree (5)	Strongly agree (6)
I feel distant from people (1)	☐	☐	☐	☐	☐	☐
I don't feel related to most people (2)	☐	☐	☐	☐	☐	☐
I feel like an outsider (3)	☐	☐	☐	☐	☐	☐
I see myself as a loner (4)	☐	☐	☐	☐	☐	☐
I feel disconnected from the world around me (5)	☐	☐	☐	☐	☐	☐
I don't feel I participate with anyone or any group (6)	☐	☐	☐	☐	☐	☐
I feel close to people (7)	☐	☐	☐	☐	☐	☐
Even around people I know, I don't feel that I really belong (8)	☐	☐	☐	☐	☐	☐
I am able to relate to my peers (9)	☐	☐	☐	☐	☐	☐
I catch myself losing a sense of connectedness with society (10)	☐	☐	☐	☐	☐	☐
I am able to connect with other people (11)	☐	☐	☐	☐	☐	☐
I feel understood by the people I know (12)	☐	☐	☐	☐	☐	☐
I see people as friendly and approachable (13)	☐	☐	☐	☐	☐	☐
I fit in well in new situations (14)	☐	☐	☐	☐	☐	☐
I have little sense of togetherness with my peers (15)	☐	☐	☐	☐	☐	☐
My friends feel like family (16)	☐	☐	☐	☐	☐	☐

I find myself actively involved
in people's lives (17)

There is no sense of
brother/sisterhood (18)

I am in tune with the world
(19)

I feel comfortable in the
presence of strangers (20)

Trait Nature Please answer each of these statements in terms of **the way you generally feel**. Using the following scale, simply state as honestly and candidly as you can what you are presently experiencing.

	Strongly disagree (1)	Disagree (2)	Neutral (3)	Agree (4)	Strongly agree (5)
I often feel a sense of oneness with the natural world around me (1)	☐	☐	☐	☐	☐
I think of the natural world as a community to which I belong (2)	☐	☐	☐	☐	☐
I recognize and appreciate the intelligence of other living organisms (3)	☐	☐	☐	☐	☐
I often feel disconnected from nature (4)	☐	☐	☐	☐	☐
When I think of my life, I imagine myself to be part of a larger cyclical process of living (5)	☐	☐	☐	☐	☐
I often feel a kinship with animals and plants (6)	☐	☐	☐	☐	☐
I feel as though I belong to the Earth as equally as it belongs to me (7)	☐	☐	☐	☐	☐
I have a deep understanding of how my actions affect the natural world (8)	☐	☐	☐	☐	☐
I often feel part of the web of life (9)	☐	☐	☐	☐	☐
I feel that all inhabitants of Earth, human, and nonhuman, share a common 'life force' (10)	☐	☐	☐	☐	☐
Like a tree can be part of a forest, I feel embedded within the broader natural world (11)	☐	☐	☐	☐	☐
When I think of my place on Earth, I consider myself to be a top member of hierarchy that exists in nature (12)	☐	☐	☐	☐	☐
I often feel like I am only a small part of the natural world around me, and that I am no more important than the grass	☐	☐	☐	☐	☐

on the ground or the birds in
the trees (13)

My personal welfare is
independent of the welfare of
the natural world (14)

End of Block: Baseline questions

Start of Block: Block 17

Video instruction 1 Please now watch this video. Once finished, please continue with the questionnaire.

End of Block: Block 17

Start of Block: Block 17

Q34 Your blood pressure and heart rate will now be recorded.

End of Block: Block 17

Start of Block: Stressor 1 Block

Well-being/Stress Using the scale below, please indicate how you feel **now**.

	Definitely not (1)	Not much (2)	Quite (3)	Definitely (4)
Nervous (1)	☐	☐	☐	☐
Tense (2)	☐	☐	☐	☐
Relaxed (3)	☐	☐	☐	☐
Calm (4)	☐	☐	☐	☐
Happy (5)	☐	☐	☐	☐
Content (6)	☐	☐	☐	☐
Sad (7)	☐	☐	☐	☐
Sorry (8)	☐	☐	☐	☐
Active (9)	☐	☐	☐	☐
Energetic (10)	☐	☐	☐	☐
Passive (11)	☐	☐	☐	☐
Sluggish (12)	☐	☐	☐	☐

Restoration We are interested in how you experience the environment you have just seen. To help us understand your experience, we have provided the following statements for you to respond to. Please read each statement carefully, and then indicate on the scale (**0 = Not at all***, **10 = Completely**) the extent to which the given statement fits your experience of the environment you have just seen.

** To respond with a value of 0, please make sure to still select the slider so that the value is recognised.*

0 1 2 3 4 5 6 7 8 9 10

That is a place which is away from everyday demands and where I would be able to relax and think about what interests me. ()	
That place is fascinating; it is large enough for me to discover and be curious about things. ()	
That is a place where the activities and the items are ordered and organized. ()	
That is a place which is very large, with no restrictions to movements; it is a world of its own. ()	
In that place, it is easy to orient and move around so that I could do what I like. ()	

End of Block: Stressor 1 Block

Start of Block: VR Instruction

Q35 You will now view an environment in virtual reality!

After, your blood pressure and heart rate will be recorded.

End of Block: VR Instruction

Start of Block: Environment 1 Block

Well-being/Stress Using the scale below, please indicate how you feel **now**.

	Definitely not (1)	Not much (2)	Quite (3)	Definitely (4)
Nervous (1)	☐	☐	☐	☐
Tense (2)	☐	☐	☐	☐
Relaxed (3)	☐	☐	☐	☐
Calm (4)	☐	☐	☐	☐

Happy (5)	☐	☐	☐	☐
Content (6)	☐	☐	☐	☐
Sad (7)	☐	☐	☐	☐
Sorry (8)	☐	☐	☐	☐
Active (9)	☐	☐	☐	☐
Energetic (10)	☐	☐	☐	☐
Passive (11)	☐	☐	☐	☐
Sluggish (12)	☐	☐	☐	☐

Restoration We are interested in how you experience the environment you have just seen. To help us understand your experience, we have provided the following statements for you to respond to. Please read each statement carefully, and then indicate on the scale (**0 = Not at all***, **10 = Completely**) the extent to which the given statement fits your experience of the environment you have just seen.

** To respond with a value of 0, please make sure to still select the slider so that the value is recognised.*

	0 1 2 3 4 5 6 7 8 9 10
That is a place which is away from everyday demands and where I would be able to relax and think about what interests me. ()	
That place is fascinating; it is large enough for me to discover and be curious about things. ()	
That is a place where the activities and the items are ordered and organized. ()	
That is a place which is very large, with no restrictions to movements; it is a world of its own. ()	

In that place, it is easy to orient and move around so that I could do what I like. ()	

State Social Please think about how you felt viewing the environment you have just seen. To what extent do each of the following statements describe how you felt?

	Strongly disagree (1)	Disagree (2)	Slightly disagree (3)	Neither agree nor disagree (4)	Slightly agree (5)	Agree (6)	Strongly agree (7)
I would feel distant from people (1)	☐	☐	☐	☐	☐	☐	☐
I would not feel related to most people (2)	☐	☐	☐	☐	☐	☐	☐
I would feel like an outsider (3)	☐	☐	☐	☐	☐	☐	☐
I would feel like I would be able to connect with other people (4)	☐	☐	☐	☐	☐	☐	☐
I would feel disconnected from the world around me (5)	☐	☐	☐	☐	☐	☐	☐
I would feel close to people (6)	☐	☐	☐	☐	☐	☐	☐
I would see people as friendly and approachable (7)	☐	☐	☐	☐	☐	☐	☐
I would feel accepted by others (8)	☐	☐	☐	☐	☐	☐	☐
I would feel like I had a sense of belonging (9)	☐	☐	☐	☐	☐	☐	☐
I would feel a strong bond with other people (10)	☐	☐	☐	☐	☐	☐	☐

End of Block: Environment 1 Block

Start of Block: Video Instruction 2

Q36 Please now watch this video. Once finished, please continue with the questionnaire.

End of Block: Video Instruction 2

Start of Block: Block 18

Q35 Your blood pressure and heart rate will now be recorded.

End of Block: Block 18

Start of Block: Stressor 2 Block

Well-being/Stress Using the scale below, please indicate how you feel **now**.

	Definitely not (1)	Not much (2)	Quite (3)	Definitely (4)
Nervous (1)	☐	☐	☐	☐
Tense (2)	☐	☐	☐	☐
Relaxed (3)	☐	☐	☐	☐
Calm (4)	☐	☐	☐	☐
Happy (5)	☐	☐	☐	☐
Content (6)	☐	☐	☐	☐
Sad (7)	☐	☐	☐	☐
Sorry (8)	☐	☐	☐	☐
Active (9)	☐	☐	☐	☐
Energetic (10)	☐	☐	☐	☐
Passive (11)	☐	☐	☐	☐
Sluggish (12)	☐	☐	☐	☐

Restoration We are interested in how you experience the environment you have just seen. To help us understand your experience, we have provided the following statements for you to respond to. Please read each statement carefully, and then indicate on the scale (**0 = Not at all***, **10 = Completely**) the extent to which the given statement fits your experience of the environment you have just seen.

** To respond with a value of 0, please make sure to still select the slider so that the value is recognised.*

	0	1	2	3	4	5	6	7	8	9	10
That is a place which is away from everyday demands and where I would be able to relax and think about what interests me. ()											
That place is fascinating; it is large enough for me to discover and be curious about things. ()											
That is a place where the activities and the items are ordered and organized. ()											
That is a place which is very large, with no restrictions to movements; it is a world of its own. ()											
In that place, it is easy to orient and move around so that I could do what I like. ()											

End of Block: Stressor 2 Block

Start of Block: VR Instruction

Q37 You will now view an environment in virtual reality!

After, your blood pressure and heart rate will be recorded.

End of Block: VR Instruction

Start of Block: Environment 2 Block

Well-being/Stress Using the scale below, please indicate how you feel **now**.

	Definitely not (1)	Not much (2)	Quite (3)	Definitely (4)
Nervous (1)	☐	☐	☐	☐
Tense (2)	☐	☐	☐	☐
Relaxed (3)	☐	☐	☐	☐
Calm (4)	☐	☐	☐	☐

Happy (5)	☐	☐	☐	☐
Content (6)	☐	☐	☐	☐
Sad (7)	☐	☐	☐	☐
Sorry (8)	☐	☐	☐	☐
Active (9)	☐	☐	☐	☐
Energetic (10)	☐	☐	☐	☐
Passive (11)	☐	☐	☐	☐
Sluggish (12)	☐	☐	☐	☐

Restoration We are interested in how you experience the environment you have just seen. To help us understand your experience, we have provided the following statements for you to respond to. Please read each statement carefully, and then indicate on the scale (**0 = Not at all***, **10 = Completely**) the extent to which the given statement fits your experience of the environment you have just seen.

** To respond with a value of 0, please make sure to still select the slider so that the value is recognised.*

	0 1 2 3 4 5 6 7 8 9 10
That is a place which is away from everyday demands and where I would be able to relax and think about what interests me. ()	
That place is fascinating; it is large enough for me to discover and be curious about things. ()	
That is a place where the activities and the items are ordered and organized. ()	
That is a place which is very large, with no restrictions to movements; it is a world of its own. ()	

In that place, it is easy to orient and move around so that I could do what I like. ()	

State Social Please think about how you felt viewing the environment you have just seen. To what extent do each of the following statements describe how you felt?

	Strongly disagree (1)	Disagree (2)	Slightly disagree (3)	Neither agree nor disagree (4)	Slightly agree (5)	Agree (6)	Strongly agree (7)
I would feel distant from people (1)	☐	☐	☐	☐	☐	☐	☐

I would not feel related to most people (2)	☐	☐	☐	☐	☐	☐	☐
I would feel like an outsider (3)	☐	☐	☐	☐	☐	☐	☐
I would feel like I would be able to connect with other people (4)	☐	☐	☐	☐	☐	☐	☐
I would feel disconnected from the world around me (5)	☐	☐	☐	☐	☐	☐	☐
I would feel close to people (6)	☐	☐	☐	☐	☐	☐	☐
I would see people as friendly and approachable (7)	☐	☐	☐	☐	☐	☐	☐
I would feel accepted by others (8)	☐	☐	☐	☐	☐	☐	☐
I would feel like I had a sense of belonging (9)	☐	☐	☐	☐	☐	☐	☐
I would feel a strong bond with other people (10)	☐	☐	☐	☐	☐	☐	☐

End of Block: Environment 2 Block

Start of Block: VR Instruction

Video instruction 3 Please now watch this video. Once finished, please continue with the questionnaire.

End of Block: VR Instruction

Start of Block: Block 19

Q36 Your blood pressure and heart rate will now be recorded.

End of Block: Block 19

Start of Block: Stressor 3 Block

Well-being/Stress Using the scale below, please indicate how you feel **now**.

	Definitely not (1)	Not much (2)	Quite (3)	Definitely (4)
Nervous (1)	☐	☐	☐	☐
Tense (2)	☐	☐	☐	☐
Relaxed (3)	☐	☐	☐	☐
Calm (4)	☐	☐	☐	☐
Happy (5)	☐	☐	☐	☐
Content (6)	☐	☐	☐	☐
Sad (7)	☐	☐	☐	☐
Sorry (8)	☐	☐	☐	☐
Active (9)	☐	☐	☐	☐
Energetic (10)	☐	☐	☐	☐
Passive (11)	☐	☐	☐	☐
Sluggish (12)	☐	☐	☐	☐

Restoration We are interested in how you experience the environment you have just seen. To help us understand your experience, we have provided the following statements for you to respond to. Please read each statement carefully, and then indicate on the scale (**0 = Not at all***, **10 = Completely**) the extent to which the given statement fits your experience of the environment you have just seen.

** To respond with a value of 0, please make sure to still select the slider so that the value is recognised.*

0 1 2 3 4 5 6 7 8 9 10

That is a place which is away from everyday demands and where I would be able to relax and think about what interests me. ()	
That place is fascinating; it is large enough for me to discover and be curious about things. ()	
That is a place where the activities and the items are ordered and organized. ()	
That is a place which is very large, with no restrictions to movements; it is a world of its own. ()	
In that place, it is easy to orient and move around so that I could do what I like. ()	

End of Block: Stressor 3 Block

Start of Block: VR Instruction

Q39 You will now view an environment in virtual reality!

After, your blood pressure and heart rate will be recorded.

End of Block: VR Instruction

Start of Block: Environment 3 Block

Well-being/Stress Using the scale below, please indicate how you feel **now**.

	Definitely not (1)	Not much (2)	Quite (3)	Definitely (4)
Nervous (1)	☐	☐	☐	☐
Tense (2)	☐	☐	☐	☐
Relaxed (3)	☐	☐	☐	☐

Calm (4)	☐	☐	☐	☐
Happy (5)	☐	☐	☐	☐
Content (6)	☐	☐	☐	☐
Sad (7)	☐	☐	☐	☐
Sorry (8)	☐	☐	☐	☐
Active (9)	☐	☐	☐	☐
Energetic (10)	☐	☐	☐	☐
Passive (11)	☐	☐	☐	☐
Sluggish (12)	☐	☐	☐	☐

Restoration We are interested in how you experience the environment you have just seen. To help us understand your experience, we have provided the following statements for you to respond to. Please read each statement carefully, and then indicate on the scale (**0 = Not at all***, **10 = Completely**) the extent to which the given statement fits your experience of the environment you have just seen.

** To respond with a value of 0, please make sure to still select the slider so that the value is recognised.*

	0 1 2 3 4 5 6 7 8 9 10
That is a place which is away from everyday demands and where I would be able to relax and think about what interests me. ()	
That place is fascinating; it is large enough for me to discover and be curious about things. ()	
That is a place where the activities and the items are ordered and organized. ()	

That is a place which is very large, with no restrictions to movements; it is a world of its own. ()	
In that place, it is easy to orient and move around so that I could do what I like. ()	

State Social Please think about how you felt viewing the environment you have just seen. To what extent do each of the following statements describe how you felt?

	Strongly disagree (1)	Disagree (2)	Slightly disagree (3)	Neither agree nor disagree (4)	Slightly agree (5)	Agree (6)	Strongly agree (7)
I would feel distant from people (1)	☐	☐	☐	☐	☐	☐	☐
I would not feel related to most people (2)	☐	☐	☐	☐	☐	☐	☐
I would feel like an outsider (3)	☐	☐	☐	☐	☐	☐	☐
I would feel like I would be able to connect with other people (4)	☐	☐	☐	☐	☐	☐	☐
I would feel disconnected from the world around me (5)	☐	☐	☐	☐	☐	☐	☐
I would feel close to people (6)	☐	☐	☐	☐	☐	☐	☐
I would see people as friendly and approachable (7)	☐	☐	☐	☐	☐	☐	☐
I would feel accepted by others (8)	☐	☐	☐	☐	☐	☐	☐

I would feel like
I had a sense of
belonging (9)

☐☐☐☐☐☐☐

I would feel a
strong bond with
other people (10)

☐☐☐☐☐☐☐

End of Block: Environment 3 Block

Start of Block: Demographic questions

Age What is your age?

Gender What is your gender?

Ethnicity What is your ethnicity?

Household type How would you describe your household?

☐ Couple with dependent children (1) ☐ Lone

parent with dependent children (2) ☐ Non-retired

couple, no dependent children (3) ☐ One non-retired

person (4) ☐ One retired person (5)

☐ Retired couple, no dependent children (6) ☐

Other multi-person household (7)

Appendix 25. Chapter 6 interview questions

1. How was your experience of viewing the VR environments? *Prompt: did you enjoy viewing the environments? Why?*
Prompt: how did you find the VR experience? Have you used VR before?
2. Is there anything in particular that attracted your attention in the videos? And why? *Prompt: the whole environment? The sounds? What was in the environment/physical things (trees, benches, people)? What did you look at?*
3. What are your thoughts around the people that were present in the environments? *Prompt: no people vs some vs crowded environment.*
4. Which environment did you prefer to be in and why?
Prompt/follow-up: how would you rank them based on preference? Was there an environment you did not like and why?
5. To what extent did you feel like you were really there in the environments? *Prompt: was the environment immersive? Did you feel present in the environments? Did the environments feel real?*
6. Do you have any comments on the quality of VR technology? E.g., how the environment was displayed in VR? Did you identify any technical issues? *Prompts: can the tech be improved at all? Was the visual clear?*
7. Do you have any additional comments?

Appendix 26. Chapter 6 quantitative analysis SPSS output

Stress

Information Criteria^a

-2 Restricted Log Likelihood	1548.0653669
Akaike's Information Criterion (AIC)	1554.0653669
Hurvich and Tsai's Criterion (AICC)	1554.1387614
Bozdogan's Criterion (CAIC)	1568.4717220
Schwarz's Bayesian Criterion (BIC)	1565.4717220

The information criteria are displayed in smaller-is-better form.

a. Dependent Variable: Stress.

Fixed Effects

Type III Tests of Fixed Effects^a

Source	Numerator df	Denominator df	F	Sig.
Intercept	1	61.752	.927	.339
Timepoint	1	284.799	113.561	<.001
Environment	2	284.798	3.571	.029
Timepoint * Environment	2	284.798	3.134	.045
Age	1	48.173	3.176	.081
Man_dummyvariable	1	46.294	.047	.829
NonW_dummyvariable	1	47.113	.658	.421
Couple_nochild_dummyvariable	1	46.427	.153	.697
Household_other_dummyvariable	1	46.379	5.922	.019
Baseline_stress	1	47.694	11.077	.002
Baseline_hedonic_tone	1	107.208	.291	.590
Baseline_energy	1	48.936	.081	.777
Loneliness	1	48.072	.473	.495
Trait_social_connectedness	1	46.462	.004	.950
Connectedness_to_nature_average	1	46.177	.491	.487

a. Dependent Variable: Stress.

2. Timepoint

Estimates^a

Timepoint	Mean	Std. Error	df	95% Confidence Interval	
				Lower Bound	Upper Bound
Pre environment	8.657 ^b	1.359	331	5.983	11.331
Post environment	6.383 ^b	1.359	331	3.709	9.057

a. Dependent Variable: Stress.

b. Covariates appearing in the model are evaluated at the following values: Age = 38.34, Man_dummyvariable = .3103, NonW_dummyvariable = .1897, Couple_nochild_dummyvariable = .2931, Household_other_dummyvariable = .3621, Baseline stress = 7.48, Baseline hedonic tone = 13.70, Baseline energy = 12.12, Loneliness = 34.28, Trait social connectedness = 92.09, Connectedness_to_nature_average = 3.6404.

Pairwise Comparisons^a

(I) Timepoint	(J) Timepoint	Mean Difference (I-J)	Std. Error	df	Sig. ^c	95% Confidence Interval for Difference ^c	
						Lower Bound	Upper Bound
Pre environment	Post environment	2.274 [*]	.213	284.799	<.001	1.854	2.694
Post environment	Pre environment	-2.274 [*]	.213	284.799	<.001	-2.694	-1.854

Based on estimated marginal means

*. The mean difference is significant at the .05 level.

a. Dependent Variable: Stress.

c. Adjustment for multiple comparisons: Bonferroni.

3. Environment

Estimates^a

Environment	Mean	Std. Error	df	95% Confidence Interval	
				Lower Bound	Upper Bound
no people	7.229 ^b	1.363	331	4.546	9.911
few people	7.424 ^b	1.363	331	4.742	10.107
lots of people	7.907 ^b	1.363	331	5.225	10.589

a. Dependent Variable: Stress.

b. Covariates appearing in the model are evaluated at the following values: Age = 38.34, Man_dummyvariable = .3103, NonW_dummyvariable = .1897, Couple_nochild_dummyvariable = .2931, Household_other_dummyvariable = .3621, Baseline stress = 7.48, Baseline hedonic tone = 13.70, Baseline energy = 12.12, Loneliness = 34.28, Trait social connectedness = 92.09, Connectedness_to_nature_average = 3.6404.

Pairwise Comparisons^a

(I) Environment	(J) Environment	Mean Difference (I-J)	Std. Error	df	Sig. ^c	95% Confidence Interval for Difference ^c	
						Lower Bound	Upper Bound
no people	few people	-.196	.261	285.028	1.000	-.825	.434
	lots of people	-.679 [*]	.261	285.028	.030	-1.308	-.049
few people	no people	.196	.261	285.028	1.000	-.434	.825
	lots of people	-.483	.261	284.337	.197	-1.112	.146
lots of people	no people	.679 [*]	.261	285.028	.030	.049	1.308
	few people	.483	.261	284.337	.197	-.146	1.112

Based on estimated marginal means

*. The mean difference is significant at the .05 level.

a. Dependent Variable: Stress.

c. Adjustment for multiple comparisons: Bonferroni.

4. Timepoint * Environment

Estimates ^a						
Timepoint	Environment	Mean	Std. Error	df	95% Confidence Interval	
					Lower Bound	Upper Bound
Pre environment	no people	8.485 ^b	1.376	331	5.778	11.191
	few people	8.812 ^b	1.376	331	6.106	11.519
	lots of people	8.674 ^b	1.376	331	5.968	11.381
Post environment	no people	5.973 ^b	1.376	331	3.266	8.679
	few people	6.037 ^b	1.376	331	3.330	8.743
	lots of people	7.140 ^b	1.376	331	4.433	9.847

a. Dependent Variable: Stress.

b. Covariates appearing in the model are evaluated at the following values: Age = 38.34, Man_dummyvariable = .3103, NonW_dummyvariable = .1897, Couple_nochild_dummyvariable = .2931, Household_other_dummyvariable = .3621, Baseline stress = 7.48, Baseline hedonic tone = 13.70, Baseline energy = 12.12, Loneliness = 34.28, Trait social connectedness = 92.09, Connectedness_to_nature_average = 3.6404.

Pairwise Comparisons ^a								
Environment	(I) Timepoint	(J) Timepoint	Mean Difference (I-J)	Std. Error	df	Sig. ^c	95% Confidence Interval for Difference ^c	
							Lower Bound	Upper Bound
no people	Pre environment	Post environment	2.512 [*]	.370	285.715	<.001	1.784	3.241
	Post environment	Pre environment	-2.512 [*]	.370	285.715	<.001	-3.241	-1.784
few people	Pre environment	Post environment	2.776 [*]	.369	284.337	<.001	2.049	3.503
	Post environment	Pre environment	-2.776 [*]	.369	284.337	<.001	-3.503	-2.049
lots of people	Pre environment	Post environment	1.534 [*]	.369	284.337	<.001	.807	2.262
	Post environment	Pre environment	-1.534 [*]	.369	284.337	<.001	-2.262	-.807

Based on estimated marginal means

*. The mean difference is significant at the .05 level.

a. Dependent Variable: Stress.

c. Adjustment for multiple comparisons: Bonferroni.

Hedonic tone

Information Criteria ^a	
-2 Restricted Log Likelihood	1409.2453578
Akaike's Information Criterion (AIC)	1415.2453578
Hurvich and Tsai's Criterion (AICC)	1415.3187523
Bozdogan's Criterion (CAIC)	1429.6517129
Schwarz's Bayesian Criterion (BIC)	1426.6517129

The information criteria are displayed in smaller-is-better form.

a. Dependent Variable: Hedonic tone.

Fixed Effects

Type III Tests of Fixed Effects^a

Source	Numerator df	Denominator df	F	Sig.
Intercept	1	60.259	10.724	.002
Timepoint	1	284.010	106.029	<.001
Environment	2	284.009	2.194	.113
Timepoint * Environment	2	284.009	1.568	.210
Age	1	47.641	.755	.389
Man_dummyvariable	1	45.636	.201	.656
NonW_dummyvariable	1	46.506	.844	.363
Couple_nochild_dummyvariable	1	45.777	.988	.325
Household_other_dummyvariable	1	45.725	2.990	.091
Baseline_stress	1	47.127	8.987	.004
Baseline_hedonic_tone	1	132.043	.777	.380
Baseline_energy	1	48.466	.078	.781
Loneliness	1	47.533	.192	.663
Trait_social_connectedness	1	45.814	.011	.918
Connectedness_to_nature_average	1	45.511	.328	.570

a. Dependent Variable: Hedonic tone.

2. Timepoint

Estimates^a

Timepoint	Mean	Std. Error	df	95% Confidence Interval	
				Lower Bound	Upper Bound
Pre environment	12.399 ^b	1.147	331	10.143	14.656
Post environment	14.141 ^b	1.147	331	11.884	16.398

a. Dependent Variable: Hedonic tone.

b. Covariates appearing in the model are evaluated at the following values: Age = 38.34, Man_dummyvariable = .3103, NonW_dummyvariable = .1897, Couple_nochild_dummyvariable = .2931, Household_other_dummyvariable = .3621, Baseline stress = 7.48, Baseline hedonic tone = 13.70, Baseline energy = 12.12, Loneliness = 34.28, Trait social connectedness = 92.09, Connectedness_to_nature_average = 3.6404.

Pairwise Comparisons^a

(I) Timepoint	(J) Timepoint	Mean Difference (I-J)	Std. Error	df	Sig. ^c	95% Confidence Interval for Difference ^c	
						Lower Bound	Upper Bound
Pre environment	Post environment	-1.741 [*]	.169	284.010	<.001	-2.074	-1.409
Post environment	Pre environment	1.741 [*]	.169	284.010	<.001	1.409	2.074

Based on estimated marginal means

*. The mean difference is significant at the .05 level.

a. Dependent Variable: Hedonic tone.

c. Adjustment for multiple comparisons: Bonferroni.

3. Environment

Estimates^a

Environment	Mean	Std. Error	df	95% Confidence Interval	
				Lower Bound	Upper Bound
no people	13.359 ^b	1.150	331	11.096	15.622
few people	13.428 ^b	1.150	331	11.165	15.691
lots of people	13.023 ^b	1.150	331	10.760	15.286

a. Dependent Variable: Hedonic tone.

b. Covariates appearing in the model are evaluated at the following values: Age = 38.34, Man_dummyvariable = .3103, NonW_dummyvariable = .1897, Couple_nochild_dummyvariable = .2931, Household_other_dummyvariable = .3621, Baseline stress = 7.48, Baseline hedonic tone = 13.70, Baseline energy = 12.12, Loneliness = 34.28, Trait social connectedness = 92.09, Connectedness_to_nature_average = 3.6404.

Pairwise Comparisons^a

(I) Environment	(J) Environment	Mean Difference (I-J)	Std. Error	df	Sig. ^b	95% Confidence Interval for Difference ^b	
						Lower Bound	Upper Bound
no people	few people	-.069	.207	284.259	1.000	-.568	.430
	lots of people	.336	.207	284.259	.317	-.163	.835
few people	no people	.069	.207	284.259	1.000	-.430	.568
	lots of people	.405	.207	283.510	.154	-.093	.904
lots of people	no people	-.336	.207	284.259	.317	-.835	.163
	few people	-.405	.207	283.510	.154	-.904	.093

Based on estimated marginal means

a. Dependent Variable: Hedonic tone.

b. Adjustment for multiple comparisons: Bonferroni.

4. Timepoint * Environment

Estimates^a

Timepoint	Environment	Mean	Std. Error	df	95% Confidence Interval	
					Lower Bound	Upper Bound
Pre environment	no people	12.652 ^b	1.160	331	10.371	14.933
	few people	12.359 ^b	1.160	331	10.078	14.640
	lots of people	12.187 ^b	1.160	331	9.906	14.468
Post environment	no people	14.066 ^b	1.160	331	11.785	16.348
	few people	14.497 ^b	1.160	331	12.216	16.778
	lots of people	13.859 ^b	1.160	331	11.578	16.140

a. Dependent Variable: Hedonic tone.

b. Covariates appearing in the model are evaluated at the following values: Age = 38.34, Man_dummyvariable = .3103, NonW_dummyvariable = .1897, Couple_nochild_dummyvariable = .2931, Household_other_dummyvariable = .3621, Baseline stress = 7.48, Baseline hedonic tone = 13.70, Baseline energy = 12.12, Loneliness = 34.28, Trait social connectedness = 92.09, Connectedness_to_nature_average = 3.6404.

Pairwise Comparisons^a

Environment	(I) Timepoint	(J) Timepoint	Mean Difference (I-J)	Std. Error	df	Sig. ^c	95% Confidence Interval for Difference ^c	
							Lower Bound	Upper Bound
no people	Pre environment	Post environment	-1.414 [*]	.293	285.001	<.001	-1.992	-.837
	Post environment	Pre environment	1.414 [*]	.293	285.001	<.001	.837	1.992
few people	Pre environment	Post environment	-2.138 [*]	.293	283.510	<.001	-2.714	-1.562
	Post environment	Pre environment	2.138 [*]	.293	283.510	<.001	1.562	2.714
lots of people	Pre environment	Post environment	-1.672 [*]	.293	283.510	<.001	-2.249	-1.096
	Post environment	Pre environment	1.672 [*]	.293	283.510	<.001	1.096	2.249

Based on estimated marginal means

*. The mean difference is significant at the .05 level.

a. Dependent Variable: Hedonic tone.

c. Adjustment for multiple comparisons: Bonferroni.

Energy

Information Criteria^a

-2 Restricted Log Likelihood	1479.3028353
Akaike's Information Criterion (AIC)	1485.3028353
Hurvich and Tsai's Criterion (AICC)	1485.3762298
Bozdogan's Criterion (CAIC)	1499.7091905
Schwarz's Bayesian Criterion (BIC)	1496.7091905

The information criteria are displayed in smaller-is-better form.

a. Dependent Variable: Energy.

Fixed Effects

Type III Tests of Fixed Effects^a

Source	Numerator df	Denominator df	F	Sig.
Intercept	1	61.605	12.007	<.001
Timepoint	1	285.119	68.680	<.001
Environment	2	285.118	.519	.596
Timepoint * Environment	2	285.118	3.840	.023
Age	1	48.851	2.818	.100
Man_dummyvariable	1	46.780	.159	.692
NonW_dummyvariable	1	47.677	1.584	.214
Couple_nochild_dummyvariable	1	46.925	1.030	.315
Household_other_dummyvariable	1	46.872	.905	.346
Baseline_stress	1	48.319	4.759	.034
Baseline_hedonic_tone	1	142.880	1.417	.236
Baseline_energy	1	49.706	6.371	.015
Loneliness	1	48.739	5.933	.019
Trait_social_connectedness	1	46.963	2.538	.118
Connectedness_to_nature_average	1	46.652	.263	.610

a. Dependent Variable: Energy.

2. Timepoint

Estimates^a

Timepoint	Mean	Std. Error	df	95% Confidence Interval	
				Lower Bound	Upper Bound
Pre environment	10.298 ^b	1.296	331	7.748	12.847
Post environment	11.846 ^b	1.296	331	9.297	14.395

a. Dependent Variable: Energy.

b. Covariates appearing in the model are evaluated at the following values: Age = 38.34, Man_dummyvariable = .3103, NonW_dummyvariable = .1897, Couple_nochild_dummyvariable = .2931, Household_other_dummyvariable = .3621, Baseline stress = 7.48, Baseline hedonic tone = 13.70, Baseline energy = 12.12, Loneliness = 34.28, Trait social connectedness = 92.09, Connectedness_to_nature_average = 3.6404.

Pairwise Comparisons^a

(I) Timepoint	(J) Timepoint	Mean Difference (I-J)	Std. Error	df	Sig. ^c	95% Confidence Interval for Difference ^c	
						Lower Bound	Upper Bound
Pre environment	Post environment	-1.549 [*]	.187	285.119	<.001	-1.916	-1.181
Post environment	Pre environment	1.549 [*]	.187	285.119	<.001	1.181	1.916

Based on estimated marginal means

*. The mean difference is significant at the .05 level.

a. Dependent Variable: Energy.

c. Adjustment for multiple comparisons: Bonferroni.

3. Environment

Estimates^a

Environment	Mean	Std. Error	df	95% Confidence Interval	
				Lower Bound	Upper Bound
no people	11.207 ^b	1.299	331	8.651	13.762
few people	11.004 ^b	1.299	331	8.449	13.560
lots of people	11.004 ^b	1.299	331	8.449	13.560

a. Dependent Variable: Energy.

b. Covariates appearing in the model are evaluated at the following values: Age = 38.34, Man_dummyvariable = .3103, NonW_dummyvariable = .1897, Couple_nochild_dummyvariable = .2931, Household_other_dummyvariable = .3621, Baseline stress = 7.48, Baseline hedonic tone = 13.70, Baseline energy = 12.12, Loneliness = 34.28, Trait social connectedness = 92.09, Connectedness_to_nature_average = 3.6404.

Pairwise Comparisons^a

(I) Environment	(J) Environment	Mean Difference (I-J)	Std. Error	df	Sig. ^b	95% Confidence Interval for Difference ^b	
						Lower Bound	Upper Bound
no people	few people	.202	.229	285.365	1.000	-.349	.753
	lots of people	.202	.229	285.365	1.000	-.349	.753
few people	no people	-.202	.229	285.365	1.000	-.753	.349
	lots of people	1.279E-13	.229	284.626	1.000	-.551	.551
lots of people	no people	-.202	.229	285.365	1.000	-.753	.349
	few people	-1.279E-13	.229	284.626	1.000	-.551	.551

Based on estimated marginal means

a. Dependent Variable: Energy.

b. Adjustment for multiple comparisons: Bonferroni.

4. Timepoint * Environment

Estimates^a

Timepoint	Environment	Mean	Std. Error	df	95% Confidence Interval	
					Lower Bound	Upper Bound
Pre environment	no people	10.798 ^b	1.309	331	8.222	13.373
	few people	10.073 ^b	1.309	331	7.498	12.649
	lots of people	10.022 ^b	1.309	331	7.446	12.597
Post environment	no people	11.616 ^b	1.309	331	9.040	14.191
	few people	11.936 ^b	1.309	331	9.360	14.511
	lots of people	11.987 ^b	1.309	331	9.412	14.563

a. Dependent Variable: Energy.

b. Covariates appearing in the model are evaluated at the following values: Age = 38.34, Man_dummyvariable = .3103, NonW_dummyvariable = .1897, Couple_nochild_dummyvariable = .2931, Household_other_dummyvariable = .3621, Baseline stress = 7.48, Baseline hedonic tone = 13.70, Baseline energy = 12.12, Loneliness = 34.28, Trait social connectedness = 92.09, Connectedness_to_nature_average = 3.6404.

Pairwise Comparisons^a

Environment	(I) Timepoint	(J) Timepoint	Mean Difference (I-J)	Std. Error	df	Sig. ^c	95% Confidence Interval for Difference ^c	
							Lower Bound	Upper Bound
no people	Pre environment	Post environment	-.818 [*]	.324	286.098	.012	-1.456	-.180
	Post environment	Pre environment	.818 [*]	.324	286.098	.012	.180	1.456
few people	Pre environment	Post environment	-1.862 [*]	.323	284.626	<.001	-2.499	-1.226
	Post environment	Pre environment	1.862 [*]	.323	284.626	<.001	1.226	2.499
lots of people	Pre environment	Post environment	-1.966 [*]	.323	284.626	<.001	-2.602	-1.329
	Post environment	Pre environment	1.966 [*]	.323	284.626	<.001	1.329	2.602

Based on estimated marginal means

*. The mean difference is significant at the .05 level.

a. Dependent Variable: Energy.

c. Adjustment for multiple comparisons: Bonferroni.

Perceived restorativeness

Information Criteria^a

-2 Restricted Log Likelihood	1290.9016716
Akaike's Information Criterion (AIC)	1296.9016716
Hurvich and Tsai's Criterion (AICC)	1296.9750661
Bozdogan's Criterion (CAIC)	1311.3080267
Schwarz's Bayesian Criterion (BIC)	1308.3080267

The information criteria are displayed in smaller-is-better form.

a. Dependent Variable: Perceived restorativeness.

Fixed Effects

Type III Tests of Fixed Effects^a

Source	Numerator df	Denominator df	F	Sig.
Intercept	1	61.972	1.654	.203
Timepoint	1	285.141	768.823	<.001
Environment	2	285.139	12.275	<.001
Timepoint * Environment	2	285.139	8.988	<.001
Age	1	48.689	.004	.949
Man_dummyvariable	1	46.708	1.672	.202
NonW_dummyvariable	1	47.570	.389	.536
Couple_nochild_dummyvariable	1	46.848	1.091	.302
Household_other_dummyvariable	1	46.797	.015	.902
Baseline_stress	1	48.183	.032	.859
Baseline_hedonic_tone	1	120.134	.071	.790
Baseline_energy	1	49.499	.491	.487
Loneliness	1	48.583	.072	.789
Trait_social_connectedness	1	46.885	.260	.613
Connectedness_to_nature_average	1	46.585	.017	.898

a. Dependent Variable: Perceived restorativeness.

3. Environment

Estimates^a

Environment	Mean	Std. Error	df	95% Confidence Interval	
				Lower Bound	Upper Bound
no people	3.764 ^b	.943	331	1.909	5.619
few people	3.494 ^b	.943	331	1.638	5.349
lots of people	2.915 ^b	.943	331	1.059	4.770

a. Dependent Variable: Perceived restorativeness.

b. Covariates appearing in the model are evaluated at the following values: Age = 38.34, Man_dummyvariable = .3103, NonW_dummyvariable = .1897, Couple_nochild_dummyvariable = .2931, Household_other_dummyvariable = .3621, Baseline stress = 7.48, Baseline hedonic tone = 13.70, Baseline energy = 12.12, Loneliness = 34.28, Trait social connectedness = 92.09, Connectedness_to_nature_average = 3.6404.

Pairwise Comparisons^a

(I) Environment	(J) Environment	Mean Difference (I-J)	Std. Error	df	Sig. ^c	95% Confidence Interval for Difference ^c	
						Lower Bound	Upper Bound
no people	few people	.270	.175	285.378	.372	-.152	.692
	lots of people	.850 [*]	.175	285.378	<.001	.428	1.272
few people	no people	-.270	.175	285.378	.372	-.692	.152
	lots of people	.579 [*]	.175	284.663	.003	.158	1.001
lots of people	no people	-.850 [*]	.175	285.378	<.001	-1.272	-.428
	few people	-.579 [*]	.175	284.663	.003	-1.001	-.158

Based on estimated marginal means

*. The mean difference is significant at the .05 level.

a. Dependent Variable: Perceived restorativeness.

c. Adjustment for multiple comparisons: Bonferroni.

State social connectedness

Information Criteria^a

-2 Restricted Log Likelihood	1218.4030430
Akaike's Information Criterion (AIC)	1224.4030430
Hurvich and Tsai's Criterion (AICC)	1224.5568892
Bozdogan's Criterion (CAIC)	1236.6285644
Schwarz's Bayesian Criterion (BIC)	1233.6285644

The information criteria are displayed in smaller-is-better form.

a. Dependent Variable: State social connectedness.

Fixed Effects

Type III Tests of Fixed Effects^a

Source	Numerator df	Denominator df	F	Sig.
Intercept	1	59.778	1.592	.212
Timepoint	0	.	.	.
Environment	2	114.191	13.708	<.001
Timepoint * Environment	0	.	.	.
Age	1	48.152	.795	.377
Man_dummyvariable	1	46.507	.557	.459
NonW_dummyvariable	1	47.181	2.732	.105
Couple_nochild_dummyvariable	1	46.685	.058	.811
Household_other_dummyvariable	1	46.764	.269	.607
Baseline_stress	1	47.861	.058	.811
Baseline_hedonic_tone	1	90.746	.422	.517
Baseline_energy	1	48.711	1.480	.230
Loneliness	1	48.139	.014	.906
Trait_social_connectedness	1	46.645	.653	.423
Connectedness_to_nature_average	1	46.516	5.996	.018

a. Dependent Variable: State social connectedness.

3. Environment

Estimates^a

Environment	Mean	Std. Error	df	95% Confidence Interval	
				Lower Bound	Upper Bound
no people	42.822 ^b	5.271	160	32.412	53.231
few people	50.089 ^b	5.271	160	39.680	60.498
lots of people	48.469 ^b	5.271	160	38.059	58.878

a. Dependent Variable: State social connectedness.

b. Covariates appearing in the model are evaluated at the following values: Age = 38.34, Man_dummyvariable = .3103, NonW_dummyvariable = .1897, Couple_nochild_dummyvariable = .2931, Household_other_dummyvariable = .3621, Baseline stress = 7.48, Baseline hedonic tone = 13.67, Baseline energy = 12.12, Loneliness = 34.28, Trait social connectedness = 92.09, Connectedness_to_nature_average = 3.6404.

Pairwise Comparisons^a

(I) Environment	(J) Environment	Mean Difference (I-J)	Std. Error	df	Sig. ^c	95% Confidence Interval for Difference ^c	
						Lower Bound	Upper Bound
no people	few people	-7.268 [*]	1.456	114.406	<.001	-10.806	-3.729
	lots of people	-5.647 [*]	1.456	114.406	<.001	-9.186	-2.108
few people	no people	7.268 [*]	1.456	114.406	<.001	3.729	10.806
	lots of people	1.621	1.453	113.765	.802	-1.911	5.152
lots of people	no people	5.647 [*]	1.456	114.406	<.001	2.108	9.186
	few people	-1.621	1.453	113.765	.802	-5.152	1.911

Based on estimated marginal means

*. The mean difference is significant at the .05 level.

a. Dependent Variable: State social connectedness.

c. Adjustment for multiple comparisons: Bonferroni.

Heart rate

Information Criteria^a

-2 Restricted Log Likelihood	1962.9381036
Akaike's Information Criterion (AIC)	1968.9381036
Hurvich and Tsai's Criterion (AICC)	1969.0191847
Bozdogan's Criterion (CAIC)	1983.0494510
Schwarz's Bayesian Criterion (BIC)	1980.0494510

The information criteria are displayed in smaller-is-better form.

a. Dependent Variable: Resting heart rate.

Fixed Effects

Type III Tests of Fixed Effects^a

Source	Numerator df	Denominator df	F	Sig.
Intercept	1	49.762	1.678	.201
Timepoint	1	256.125	1.684	.196
Environment	2	256.030	2.757	.065
Timepoint * Environment	2	256.024	2.602	.076
Age	1	43.875	1.540	.221
Man_dummyvariable	1	43.858	.659	.421
NonW_dummyvariable	1	44.362	5.463	.024
Couple_nochild_dummyvariable	1	43.885	.581	.450
Household_other_dummyvariable	1	43.689	.996	.324
Baseline_stress	1	44.270	.561	.458
Baseline_hedonic_tone	1	290.788	1.460	.228
Baseline_energy	1	44.374	6.535	.014
Loneliness	1	44.396	2.281	.138
Trait_social_connectedness	1	43.433	4.756	.035
Connectedness_to_nature_average	1	43.920	.049	.825

a. Dependent Variable: Resting heart rate.

2. Timepoint

Estimates^a

Timepoint	Mean	Std. Error	df	95% Confidence Interval	
				Lower Bound	Upper Bound
Pre environment	72.085 ^b	6.975	300	58.359	85.810
Post environment	71.483 ^b	6.975	300	57.756	85.209

a. Dependent Variable: Resting heart rate.

b. Covariates appearing in the model are evaluated at the following values: Age = 37.70, Man_dummyvariable = .2618, NonW_dummyvariable = .1924, Couple_nochild_dummyvariable = .2776, Household_other_dummyvariable = .3438, Baseline_stress = 7.56, Baseline hedonic tone = 13.58, Baseline energy = 12.05, Loneliness = 34.18, Trait social connectedness = 92.37, Connectedness_to_nature_average = 3.6478.

Pairwise Comparisons^a

(I) Timepoint	(J) Timepoint	Mean Difference (I-J)	Std. Error	df	Sig. ^b	95% Confidence Interval for Difference ^b	
						Lower Bound	Upper Bound
Pre environment	Post environment	.602	.464	256.125	.196	-.311	1.514
Post environment	Pre environment	-.602	.464	256.125	.196	-1.514	.311

Based on estimated marginal means

a. Dependent Variable: Resting heart rate.

b. Adjustment for multiple comparisons: Bonferroni.

3. Environment

Estimates^a

Environment	Mean	Std. Error	df	95% Confidence Interval	
				Lower Bound	Upper Bound
no people	72.551 ^b	6.979	300	58.818	86.284
few people	71.403 ^b	6.979	300	57.669	85.136
lots of people	71.398 ^b	6.979	300	57.664	85.131

a. Dependent Variable: Resting heart rate.

b. Covariates appearing in the model are evaluated at the following values: Age = 37.70, Man_dummyvariable = .2618, NonW_dummyvariable = .1924, Couple_nochild_dummyvariable = .2776, Household_other_dummyvariable = .3438, Baseline stress = 7.56, Baseline hedonic tone = 13.58, Baseline energy = 12.05, Loneliness = 34.18, Trait social connectedness = 92.37, Connectedness_to_nature_average = 3.6478.

Pairwise Comparisons^a

(I) Environment	(J) Environment	Mean Difference (I-J)	Std. Error	df	Sig. ^b	95% Confidence Interval for Difference ^b	
						Lower Bound	Upper Bound
no people	few people	1.149	.566	256.215	.130	-.214	2.511
	lots of people	1.154	.566	256.049	.127	-.209	2.517
few people	no people	-1.149	.566	256.215	.130	-2.511	.214
	lots of people	.005	.564	255.826	1.000	-1.354	1.364
lots of people	no people	-1.154	.566	256.049	.127	-2.517	.209
	few people	-.005	.564	255.826	1.000	-1.364	1.354

Based on estimated marginal means

a. Dependent Variable: Resting heart rate.

b. Adjustment for multiple comparisons: Bonferroni.

4. Timepoint * Environment

Estimates^a

Timepoint	Environment	Mean	Std. Error	df	95% Confidence Interval	
					Lower Bound	Upper Bound
Pre environment	no people	73.219 ^b	6.989	300	59.465	86.973
	few people	72.080 ^b	6.989	300	58.326	85.834
	lots of people	70.955 ^b	6.990	300	57.199	84.710
Post environment	no people	71.883 ^b	6.991	300	58.126	85.641
	few people	70.725 ^b	6.991	300	56.968	84.482
	lots of people	71.840 ^b	6.991	300	58.084	85.597

a. Dependent Variable: Resting heart rate.

b. Covariates appearing in the model are evaluated at the following values: Age = 37.70, Man_dummyvariable = .2618, NonW_dummyvariable = .1924, Couple_nochild_dummyvariable = .2776, Household_other_dummyvariable = .3438, Baseline stress = 7.56, Baseline hedonic tone = 13.58, Baseline energy = 12.05, Loneliness = 34.18, Trait social connectedness = 92.37, Connectedness_to_nature_average = 3.6478.

Pairwise Comparisons^a

Environment	(I) Timepoint	(J) Timepoint	Mean Difference (I-J)	Std. Error	df	Sig. ^b	95% Confidence Interval for Difference ^b	
							Lower Bound	Upper Bound
no people	Pre environment	Post environment	1.336	.803	256.442	.098	-.246	2.917
	Post environment	Pre environment	-1.336	.803	256.442	.098	-2.917	.246
few people	Pre environment	Post environment	1.355	.799	256.035	.091	-.218	2.928
	Post environment	Pre environment	-1.355	.799	256.035	.091	-2.928	.218
lots of people	Pre environment	Post environment	-.886	.799	255.694	.269	-2.460	.688
	Post environment	Pre environment	.886	.799	255.694	.269	-.688	2.460

Based on estimated marginal means

a. Dependent Variable: Resting heart rate.

b. Adjustment for multiple comparisons: Bonferroni.

Systolic blood pressure

Information Criteria^a

-2 Restricted Log Likelihood	2148.3278972
Akaike's Information Criterion (AIC)	2154.3278972
Hurvich and Tsai's Criterion (AICC)	2154.4089783
Bozdogan's Criterion (CAIC)	2168.4392446
Schwarz's Bayesian Criterion (BIC)	2165.4392446

The information criteria are displayed in smaller-is-better form.

a. Dependent Variable: Resting systolic blood pressure.

Fixed Effects

Type III Tests of Fixed Effects^a

Source	Numerator df	Denominator df	F	Sig.
Intercept	1	55.593	18.006	<.001
Timepoint	1	257.505	4.475	.035
Environment	2	257.024	6.426	.002
Timepoint * Environment	2	257.013	.177	.838
Age	1	44.173	.399	.531
Man_dummyvariable	1	44.228	4.758	.035
NonW_dummyvariable	1	45.699	.182	.672
Couple_nochild_dummyvariable	1	44.350	.870	.356
Household_other_dummyvariable	1	43.625	3.974	.052
Baseline_stress	1	45.263	.004	.952
Baseline_hedonic_tone	1	253.394	.198	.657
Baseline_energy	1	45.485	.690	.411
Loneliness	1	45.562	.144	.706
Trait_social_connectedness	1	42.925	.241	.626
Connectedness_to_nature_average	1	44.444	1.908	.174

a. Dependent Variable: Resting systolic blood pressure.

2. Timepoint

Estimates^a

Timepoint	Mean	Std. Error	df	95% Confidence Interval	
				Lower Bound	Upper Bound
Pre environment	124.322 ^b	5.853	300	112.803	135.840
Post environment	122.833 ^b	5.854	300	111.312	134.354

a. Dependent Variable: Resting systolic blood pressure.

b. Covariates appearing in the model are evaluated at the following values: Age = 37.70, Man_dummyvariable = .2618, NonW_dummyvariable = .1924, Couple_nochild_dummyvariable = .2776, Household_other_dummyvariable = .3438, Baseline stress = 7.56, Baseline hedonic tone = 13.58, Baseline energy = 12.05, Loneliness = 34.18, Trait social connectedness = 92.37, Connectedness_to_nature_average = 3.6478.

Pairwise Comparisons^a

(I) Timepoint	(J) Timepoint	Mean Difference (I-J)	Std. Error	df	Sig. ^c	95% Confidence Interval for Difference ^c	
						Lower Bound	Upper Bound
Pre environment	Post environment	1.489 [*]	.704	257.505	.035	.103	2.875
Post environment	Pre environment	-1.489 [*]	.704	257.505	.035	-2.875	-.103

Based on estimated marginal means

*. The mean difference is significant at the .05 level.

a. Dependent Variable: Resting systolic blood pressure.

c. Adjustment for multiple comparisons: Bonferroni.

3. Environment

Estimates^a

Environment	Mean	Std. Error	df	95% Confidence Interval	
				Lower Bound	Upper Bound
no people	125.303 ^b	5.864	300	113.763	136.842
few people	122.343 ^b	5.864	300	110.803	133.882
lots of people	123.086 ^b	5.865	300	111.545	134.627

a. Dependent Variable: Resting systolic blood pressure.

b. Covariates appearing in the model are evaluated at the following values: Age = 37.70, Man_dummyvariable = .2618, NonW_dummyvariable = .1924, Couple_nochild_dummyvariable = .2776, Household_other_dummyvariable = .3438, Baseline stress = 7.56, Baseline hedonic tone = 13.58, Baseline energy = 12.05, Loneliness = 34.18, Trait social connectedness = 92.37, Connectedness_to_nature_average = 3.6478.

Pairwise Comparisons^a

(I) Environment	(J) Environment	Mean Difference (I-J)	Std. Error	df	Sig. ^c	95% Confidence Interval for Difference ^c	
						Lower Bound	Upper Bound
no people	few people	2.960 [*]	.859	257.573	.002	.891	5.029
	lots of people	2.217 [*]	.859	257.060	.031	.147	4.287
few people	no people	-2.960 [*]	.859	257.573	.002	-5.029	-.891
	lots of people	-.743	.857	256.446	1.000	-2.809	1.323
lots of people	no people	-2.217 [*]	.859	257.060	.031	-4.287	-.147
	few people	.743	.857	256.446	1.000	-1.323	2.809

Based on estimated marginal means

*. The mean difference is significant at the .05 level.

a. Dependent Variable: Resting systolic blood pressure.

c. Adjustment for multiple comparisons: Bonferroni.

4. Timepoint * Environment

Estimates ^a							
Timepoint	Environment	Mean	Std. Error	df	95% Confidence Interval		
					Lower Bound	Upper Bound	
Pre environment	no people	126.081 ^b	5.894	300	114.483	137.679	
	few people	123.323 ^b	5.894	300	111.725	134.921	
	lots of people	123.560 ^b	5.895	300	111.959	135.161	
Post environment	no people	124.524 ^b	5.897	300	112.919	136.129	
	few people	121.362 ^b	5.897	300	109.758	132.966	
	lots of people	122.612 ^b	5.897	300	111.008	134.216	

a. Dependent Variable: Resting systolic blood pressure.

b. Covariates appearing in the model are evaluated at the following values: Age = 37.70, Man_dummyvariable = .2618, NonW_dummyvariable = .1924, Couple_nochild_dummyvariable = .2776, Household_other_dummyvariable = .3438, Baseline stress = 7.56, Baseline hedonic tone = 13.58, Baseline energy = 12.05, Loneliness = 34.18, Trait social connectedness = 92.37, Connectedness_to_nature_average = 3.6478.

Pairwise Comparisons ^a								
Environment	(I) Timepoint	(J) Timepoint	Mean Difference (I-J)	Std. Error	df	Sig. ^b	95% Confidence Interval for Difference ^b	
							Lower Bound	Upper Bound
no people	Pre environment	Post environment	1.557	1.219	258.299	.202	-.842	3.957
	Post environment	Pre environment	-1.557	1.219	258.299	.202	-3.957	.842
few people	Pre environment	Post environment	1.962	1.213	257.128	.107	-.428	4.351
	Post environment	Pre environment	-1.962	1.213	257.128	.107	-4.351	.428
lots of people	Pre environment	Post environment	.948	1.215	256.100	.436	-1.444	3.340
	Post environment	Pre environment	-.948	1.215	256.100	.436	-3.340	1.444

Based on estimated marginal means

a. Dependent Variable: Resting systolic blood pressure.

b. Adjustment for multiple comparisons: Bonferroni.

Diastolic blood pressure

Information Criteria ^a	
-2 Restricted Log Likelihood	2015.4212999
Akaike's Information Criterion (AIC)	2021.4212999
Hurvich and Tsai's Criterion (AICC)	2021.5023809
Bozdogan's Criterion (CAIC)	2035.5326473
Schwarz's Bayesian Criterion (BIC)	2032.5326473

The information criteria are displayed in smaller-is-better form.

a. Dependent Variable: Resting diastolic blood pressure.

Fixed Effects

Type III Tests of Fixed Effects^a

Source	Numerator df	Denominator df	F	Sig.
Intercept	1	53.436	9.294	.004
Timepoint	1	256.421	8.780	.003
Environment	2	256.072	5.176	.006
Timepoint * Environment	2	256.061	3.793	.024
Age	1	43.442	1.171	.285
Man_dummyvariable	1	43.460	.168	.684
NonW_dummyvariable	1	44.683	.200	.657
Couple_nochild_dummyvariable	1	43.553	.308	.582
Household_other_dummyvariable	1	42.990	.758	.389
Baseline_stress	1	44.363	.186	.668
Baseline_hedonic_tone	1	282.013	.150	.699
Baseline_energy	1	44.565	.012	.913
Loneliness	1	44.629	.119	.731
Trait_social_connectedness	1	42.397	.020	.889
Connectedness_to_nature_average	1	43.630	.135	.715

a. Dependent Variable: Resting diastolic blood pressure.

2. Timepoint

Estimates^a

Timepoint	Mean	Std. Error	df	95% Confidence Interval	
				Lower Bound	Upper Bound
Pre environment	84.327 ^b	5.081	300	74.328	94.326
Post environment	82.693 ^b	5.082	300	72.692	92.695

a. Dependent Variable: Resting diastolic blood pressure.

b. Covariates appearing in the model are evaluated at the following values: Age = 37.70, Man_dummyvariable = .2618, NonW_dummyvariable = .1924, Couple_nochild_dummyvariable = .2776, Household_other_dummyvariable = .3438, Baseline stress = 7.56, Baseline hedonic tone = 13.58, Baseline energy = 12.05, Loneliness = 34.18, Trait social connectedness = 92.37, Connectedness_to_nature_average = 3.6478.

Pairwise Comparisons^a

(I) Timepoint	(J) Timepoint	Mean Difference (I-J)	Std. Error	df	Sig. ^c	95% Confidence Interval for Difference ^c	
						Lower Bound	Upper Bound
Pre environment	Post environment	1.634 [*]	.551	256.421	.003	.548	2.720
Post environment	Pre environment	-1.634 [*]	.551	256.421	.003	-2.720	-.548

Based on estimated marginal means

*. The mean difference is significant at the .05 level.

a. Dependent Variable: Resting diastolic blood pressure.

c. Adjustment for multiple comparisons: Bonferroni.

3. Environment

Estimates^a

Environment	Mean	Std. Error	df	95% Confidence Interval	
				Lower Bound	Upper Bound
no people	84.662 ^b	5.089	300	74.648	94.677
few people	82.514 ^b	5.089	300	72.500	92.529
lots of people	83.354 ^b	5.089	300	73.338	93.369

a. Dependent Variable: Resting diastolic blood pressure.

b. Covariates appearing in the model are evaluated at the following values: Age = 37.70, Man_dummyvariable = .2618, NonW_dummyvariable = .1924, Couple_nochild_dummyvariable = .2776, Household_other_dummyvariable = .3438, Baseline stress = 7.56, Baseline hedonic tone = 13.58, Baseline energy = 12.05, Loneliness = 34.18, Trait social connectedness = 92.37, Connectedness_to_nature_average = 3.6478.

Pairwise Comparisons^a

(I) Environment	(J) Environment	Mean Difference (I-J)	Std. Error	df	Sig. ^c	95% Confidence Interval for Difference ^c	
						Lower Bound	Upper Bound
no people	few people	2.148 [*]	.673	256.537	.005	.527	3.769
	lots of people	1.309	.673	256.107	.159	-.313	2.930
few people	no people	-2.148 [*]	.673	256.537	.005	-3.769	-.527
	lots of people	-.839	.671	255.577	.637	-2.457	.779
lots of people	no people	-1.309	.673	256.107	.159	-2.930	.313
	few people	.839	.671	255.577	.637	-.779	2.457

Based on estimated marginal means

*. The mean difference is significant at the .05 level.

a. Dependent Variable: Resting diastolic blood pressure.

c. Adjustment for multiple comparisons: Bonferroni.

4. Timepoint * Environment

Estimates^a

Timepoint	Environment	Mean	Std. Error	df	95% Confidence Interval	
					Lower Bound	Upper Bound
Pre environment	no people	86.185 ^b	5.110	300	76.129	96.241
	few people	83.674 ^b	5.110	300	73.618	93.730
	lots of people	83.122 ^b	5.111	300	73.064	93.180
Post environment	no people	83.140 ^b	5.113	300	73.079	93.201
	few people	81.355 ^b	5.112	300	71.294	91.415
	lots of people	83.585 ^b	5.112	300	73.525	93.646

a. Dependent Variable: Resting diastolic blood pressure.

b. Covariates appearing in the model are evaluated at the following values: Age = 37.70, Man_dummyvariable = .2618, NonW_dummyvariable = .1924, Couple_nochild_dummyvariable = .2776, Household_other_dummyvariable = .3438, Baseline stress = 7.56, Baseline hedonic tone = 13.58, Baseline energy = 12.05, Loneliness = 34.18, Trait social connectedness = 92.37, Connectedness_to_nature_average = 3.6478.

Pairwise Comparisons^a

Environment	(I) Timepoint	(J) Timepoint	Mean Difference (I-J)	Std. Error	df	Sig. ^c	95% Confidence Interval for Difference ^c	
							Lower Bound	Upper Bound
no people	Pre environment	Post environment	3.045 [*]	.955	257.135	.002	1.165	4.926
	Post environment	Pre environment	-3.045 [*]	.955	257.135	.002	-4.926	-1.165
few people	Pre environment	Post environment	2.320 [*]	.950	256.135	.015	.448	4.191
	Post environment	Pre environment	-2.320 [*]	.950	256.135	.015	-4.191	-.448
lots of people	Pre environment	Post environment	-.463	.951	255.269	.627	-2.337	1.410
	Post environment	Pre environment	.463	.951	255.269	.627	-1.410	2.337

Based on estimated marginal means

*. The mean difference is significant at the .05 level.

a. Dependent Variable: Resting diastolic blood pressure.

c. Adjustment for multiple comparisons: Bonferroni.

Appendix 27. Chapter 6 quantitative analysis age differences

Stress – younger adults (18-24 yrs)

Information Criteria^a

-2 Restricted Log Likelihood	827.43167427
Akaike's Information Criterion (AIC)	833.43167427
Hurvich and Tsai's Criterion (AICC)	833.57712881
Bozdogan's Criterion (CAIC)	845.82137041
Schwarz's Bayesian Criterion (BIC)	842.82137041

The information criteria are displayed in smaller-is-better form.

a. Dependent Variable: Stress.

Fixed Effects

Type III Tests of Fixed Effects^a

Source	Numerator df	Denominator df	F	Sig.
Intercept	1	20.078	.009	.924
Timepoint	1	150.000	70.463	<.001
Environment	2	150.000	.652	.522
Timepoint * Environment	2	150.000	1.533	.219
Age	1	19.020	.948	.342
Man_dummyvariable	1	19.020	1.403	.251
NonW_dummyvariable	1	19.020	1.002	.329
Couple_nochild_dummyvariable	1	19.020	2.204	.154
Household_other_dummyvariable	1	19.020	3.849	.065
Baseline_stress	1	19.020	7.450	.013
Baseline_hedonic_tone	1	19.020	.051	.823
Baseline_energy	1	19.020	.849	.368
Loneliness	1	19.020	.767	.392
Trait_social_connectedness	1	19.020	.511	.483
Connectedness_to_nature_average	1	19.020	1.732	.204

a. Dependent Variable: Stress.

2. Timepoint

Estimates^a

Timepoint	Mean	Std. Error	df	95% Confidence Interval	
				Lower Bound	Upper Bound
Pre environment	9.194 ^b	1.381	169	6.467	11.920
Post environment	6.677 ^b	1.381	169	3.951	9.404

a. Dependent Variable: Stress.

b. Covariates appearing in the model are evaluated at the following values: Age = 30.26, Man_dummyvariable = .3226, NonW_dummyvariable = .2581, Couple_nochild_dummyvariable = .3548, Household_other_dummyvariable = .3871, Baseline stress = 7.42, Baseline hedonic tone = 13.45, Baseline energy = 12.39, Loneliness = 34.48, Trait social connectedness = 91.81, Connectedness_to_nature_average = 3.5461.

Pairwise Comparisons^a

(I) Timepoint	(J) Timepoint	Mean Difference (I-J)	Std. Error	df	Sig. ^c	95% Confidence Interval for Difference ^c	
						Lower Bound	Upper Bound
Pre environment	Post environment	2.516 [*]	.300	150.000	<.001	1.924	3.108
Post environment	Pre environment	-2.516 [*]	.300	150.000	<.001	-3.108	-1.924

Based on estimated marginal means

*. The mean difference is significant at the .05 level.

a. Dependent Variable: Stress.

c. Adjustment for multiple comparisons: Bonferroni.

3. Environment

Estimates^a

Environment	Mean	Std. Error	df	95% Confidence Interval	
				Lower Bound	Upper Bound
no people	7.726 ^b	1.389	169	4.983	10.469
few people	7.935 ^b	1.389	169	5.193	10.678
lots of people	8.145 ^b	1.389	169	5.402	10.888

a. Dependent Variable: Stress.

b. Covariates appearing in the model are evaluated at the following values: Age = 30.26, Man_dummyvariable = .3226, NonW_dummyvariable = .2581, Couple_nochild_dummyvariable = .3548, Household_other_dummyvariable = .3871, Baseline stress = 7.42, Baseline hedonic tone = 13.45, Baseline energy = 12.39, Loneliness = 34.48, Trait social connectedness = 91.81, Connectedness_to_nature_average = 3.5461.

Pairwise Comparisons^a

(I) Environment	(J) Environment	Mean Difference (I-J)	Std. Error	df	Sig. ^b	95% Confidence Interval for Difference ^b	
						Lower Bound	Upper Bound
no people	few people	-.210	.367	150.000	1.000	-1.099	.679
	lots of people	-.419	.367	150.000	.765	-1.308	.469
few people	no people	.210	.367	150.000	1.000	-.679	1.099
	lots of people	-.210	.367	150.000	1.000	-1.099	.679
lots of people	no people	.419	.367	150.000	.765	-.469	1.308
	few people	.210	.367	150.000	1.000	-.679	1.099

Based on estimated marginal means

a. Dependent Variable: Stress.

b. Adjustment for multiple comparisons: Bonferroni.

4. Timepoint * Environment

Estimates^a

Timepoint	Environment	Mean	Std. Error	df	95% Confidence Interval	
					Lower Bound	Upper Bound
Pre environment	no people	9.161 ^b	1.413	169	6.371	11.952
	few people	9.387 ^b	1.413	169	6.597	12.177
	lots of people	9.032 ^b	1.413	169	6.242	11.823
Post environment	no people	6.290 ^b	1.413	169	3.500	9.081
	few people	6.484 ^b	1.413	169	3.694	9.274
	lots of people	7.258 ^b	1.413	169	4.468	10.048

a. Dependent Variable: Stress.

b. Covariates appearing in the model are evaluated at the following values: Age = 30.26, Man_dummyvariable = .3226, NonW_dummyvariable = .2581, Couple_nochild_dummyvariable = .3548, Household_other_dummyvariable = .3871, Baseline stress = 7.42, Baseline hedonic tone = 13.45, Baseline energy = 12.39, Loneliness = 34.48, Trait social connectedness = 91.81, Connectedness_to_nature_average = 3.5461.

Pairwise Comparisons^a

Environment	(I) Timepoint	(J) Timepoint	Mean Difference (I-J)	Std. Error	df	Sig. ^c	95% Confidence Interval for Difference ^c	
							Lower Bound	Upper Bound
no people	Pre environment	Post environment	2.871 [*]	.519	150.000	<.001	1.845	3.897
	Post environment	Pre environment	-2.871 [*]	.519	150.000	<.001	-3.897	-1.845
few people	Pre environment	Post environment	2.903 [*]	.519	150.000	<.001	1.877	3.929
	Post environment	Pre environment	-2.903 [*]	.519	150.000	<.001	-3.929	-1.877
lots of people	Pre environment	Post environment	1.774 [*]	.519	150.000	<.001	.748	2.800
	Post environment	Pre environment	-1.774 [*]	.519	150.000	<.001	-2.800	-.748

Based on estimated marginal means

*. The mean difference is significant at the .05 level.

a. Dependent Variable: Stress.

c. Adjustment for multiple comparisons: Bonferroni.

Stress – middle to older adults

Information Criteria^a

-2 Restricted Log Likelihood	698.95840138
Akaike's Information Criterion (AIC)	704.95840138
Hurvich and Tsai's Criterion (AICC)	705.12861415
Bozdogan's Criterion (CAIC)	716.88860261
Schwarz's Bayesian Criterion (BIC)	713.88860261

The information criteria are displayed in smaller-is-better form.

a. Dependent Variable: Stress.

Fixed Effects

Type III Tests of Fixed Effects^a

Source	Numerator df	Denominator df	F	Sig.
Intercept	1	17.387	.847	.370
Timepoint	1	129.454	42.532	<.001
Environment	2	129.450	3.812	.025
Timepoint * Environment	2	129.450	1.712	.185
Age	1	18.545	.424	.523
Man_dummyvariable	1	15.255	2.562	.130
NonW_dummyvariable	1	16.312	2.037	.172
Couple_nochild_dummyvariable	1	16.641	1.099	.309
Household_other_dummyvariable	1	15.309	5.094	.039
Baseline_stress	1	16.330	4.669	.046
Baseline_hedonic_tone	1	86.042	.005	.945
Baseline_energy	1	15.547	.001	.974
Loneliness	1	15.666	.005	.943
Trait_social_connectedness	1	15.313	.001	.971
Connectedness_to_nature_average	1	16.005	3.073	.099

a. Dependent Variable: Stress.

2. Timepoint

Estimates^a

Timepoint	Mean	Std. Error	df	95% Confidence Interval	
				Lower Bound	Upper Bound
Pre environment	8.038 ^b	1.288	145	5.493	10.583
Post environment	6.049 ^b	1.288	145	3.504	8.594

a. Dependent Variable: Stress.

b. Covariates appearing in the model are evaluated at the following values: Age = 47.63, Man_dummyvariable = .2963, NonW_dummyvariable = .1111, Couple_nochild_dummyvariable = .2222, Household_other_dummyvariable = .3333, Baseline stress = 7.56, Baseline hedonic tone = 13.98, Baseline energy = 11.81, Loneliness = 34.04, Trait social connectedness = 92.41, Connectedness_to_nature_average = 3.7487.

Pairwise Comparisons^a

(I) Timepoint	(J) Timepoint	Mean Difference (I-J)	Std. Error	df	Sig. ^c	95% Confidence Interval for Difference ^c	
						Lower Bound	Upper Bound
Pre environment	Post environment	1.989 [*]	.305	129.454	<.001	1.386	2.593
Post environment	Pre environment	-1.989 [*]	.305	129.454	<.001	-2.593	-1.386

Based on estimated marginal means

*. The mean difference is significant at the .05 level.

a. Dependent Variable: Stress.

c. Adjustment for multiple comparisons: Bonferroni.

3. Environment

Estimates^a

Environment	Mean	Std. Error	df	95% Confidence Interval	
				Lower Bound	Upper Bound
no people	6.665 ^b	1.297	145	4.102	9.228
few people	6.834 ^b	1.297	145	4.271	9.397
lots of people	7.630 ^b	1.297	145	5.068	10.193

a. Dependent Variable: Stress.

b. Covariates appearing in the model are evaluated at the following values: Age = 47.63, Man_dummyvariable = .2963, NonW_dummyvariable = .1111, Couple_nochild_dummyvariable = .2222, Household_other_dummyvariable = .3333, Baseline stress = 7.56, Baseline hedonic tone = 13.98, Baseline energy = 11.81, Loneliness = 34.04, Trait social connectedness = 92.41, Connectedness_to_nature_average = 3.7487.

Pairwise Comparisons^a

(I) Environment	(J) Environment	Mean Difference (I-J)	Std. Error	df	Sig. ^c	95% Confidence Interval for Difference ^c	
						Lower Bound	Upper Bound
no people	few people	-.169	.374	129.682	1.000	-1.076	.738
	lots of people	-.965 [*]	.374	129.682	.033	-1.872	-.058
few people	no people	.169	.374	129.682	1.000	-.738	1.076
	lots of people	-.796	.373	128.989	.103	-1.700	.108
lots of people	no people	.965 [*]	.374	129.682	.033	.058	1.872
	few people	.796	.373	128.989	.103	-.108	1.700

Based on estimated marginal means

*. The mean difference is significant at the .05 level.

a. Dependent Variable: Stress.

c. Adjustment for multiple comparisons: Bonferroni.

4. Timepoint * Environment

Estimates^a

Timepoint	Environment	Mean	Std. Error	df	95% Confidence Interval	
					Lower Bound	Upper Bound
Pre environment	no people	7.704 ^b	1.323	145	5.089	10.319
	few people	8.149 ^b	1.323	145	5.534	10.764
	lots of people	8.260 ^b	1.323	145	5.645	10.875
Post environment	no people	5.626 ^b	1.324	145	3.009	8.243
	few people	5.519 ^b	1.323	145	2.904	8.134
	lots of people	7.001 ^b	1.323	145	4.386	9.616

a. Dependent Variable: Stress.

b. Covariates appearing in the model are evaluated at the following values: Age = 47.63, Man_dummyvariable = .2963, NonW_dummyvariable = .1111, Couple_nochild_dummyvariable = .2222, Household_other_dummyvariable = .3333, Baseline stress = 7.56, Baseline hedonic tone = 13.98, Baseline energy = 11.81, Loneliness = 34.04, Trait social connectedness = 92.41, Connectedness_to_nature_average = 3.7487.

Pairwise Comparisons^a

Environment	(I) Timepoint	(J) Timepoint	Mean Difference (I-J)	Std. Error	df	Sig. ^c	95% Confidence Interval for Difference ^c	
							Lower Bound	Upper Bound
no people	Pre environment	Post environment	2.079 [*]	.531	130.355	<.001	1.028	3.129
	Post environment	Pre environment	-2.079 [*]	.531	130.355	<.001	-3.129	-1.028
few people	Pre environment	Post environment	2.630 [*]	.527	128.989	<.001	1.587	3.672
	Post environment	Pre environment	-2.630 [*]	.527	128.989	<.001	-3.672	-1.587
lots of people	Pre environment	Post environment	1.259 [*]	.527	128.989	.018	.217	2.302
	Post environment	Pre environment	-1.259 [*]	.527	128.989	.018	-2.302	-.217

Based on estimated marginal means

*. The mean difference is significant at the .05 level.

a. Dependent Variable: Stress.

c. Adjustment for multiple comparisons: Bonferroni.

Hedonic tone – younger adults (18-24 yrs)

Information Criteria^a

-2 Restricted Log Likelihood	772.36549544
Akaike's Information Criterion (AIC)	778.36549544
Hurvich and Tsai's Criterion (AICC)	778.51094999
Bozdogan's Criterion (CAIC)	790.75519159
Schwarz's Bayesian Criterion (BIC)	787.75519159

The information criteria are displayed in smaller-is-better form.

a. Dependent Variable: Hedonic tone.

Fixed Effects

Type III Tests of Fixed Effects^a

Source	Numerator df	Denominator df	F	Sig.
Intercept	1	19.857	2.462	.132
Timepoint	1	150.000	57.954	<.001
Environment	2	150.000	.355	.702
Timepoint * Environment	2	150.000	.466	.628
Age	1	19.020	.810	.379
Man_dummyvariable	1	19.020	.153	.700
NonW_dummyvariable	1	19.020	.394	.538
Couple_nochild_dummyvariable	1	19.020	.068	.797
Household_other_dummyvariable	1	19.020	2.253	.150
Baseline_stress	1	19.020	.555	.465
Baseline_hedonic_tone	1	19.020	.774	.390
Baseline_energy	1	19.020	1.200	.287
Loneliness	1	19.020	.010	.922
Trait_social_connectedness	1	19.020	.530	.476
Connectedness_to_nature_average	1	19.020	.048	.828

a. Dependent Variable: Hedonic tone.

2. Timepoint

Estimates^a

Timepoint	Mean	Std. Error	df	95% Confidence Interval	
				Lower Bound	Upper Bound
Pre environment	12.065 ^b	1.216	169	9.664	14.465
Post environment	13.968 ^b	1.216	169	11.568	16.368

a. Dependent Variable: Hedonic tone.

b. Covariates appearing in the model are evaluated at the following values: Age = 30.26, Man_dummyvariable = .3226, NonW_dummyvariable = .2581, Couple_nochild_dummyvariable = .3548, Household_other_dummyvariable = .3871, Baseline stress = 7.42, Baseline hedonic tone = 13.45, Baseline energy = 12.39, Loneliness = 34.48, Trait social connectedness = 91.81, Connectedness_to_nature_average = 3.5461.

Pairwise Comparisons^a

(I) Timepoint	(J) Timepoint	Mean Difference (I-J)	Std. Error	df	Sig. ^c	95% Confidence Interval for Difference ^c	
						Lower Bound	Upper Bound
Pre environment	Post environment	-1.903 [*]	.250	150.000	<.001	-2.397	-1.409
Post environment	Pre environment	1.903 [*]	.250	150.000	<.001	1.409	2.397

Based on estimated marginal means

*. The mean difference is significant at the .05 level.

a. Dependent Variable: Hedonic tone.

c. Adjustment for multiple comparisons: Bonferroni.

3. Environment

Estimates^a

Environment	Mean	Std. Error	df	95% Confidence Interval	
				Lower Bound	Upper Bound
no people	13.016 ^b	1.222	169	10.603	15.429
few people	13.145 ^b	1.222	169	10.732	15.558
lots of people	12.887 ^b	1.222	169	10.474	15.300

a. Dependent Variable: Hedonic tone.

b. Covariates appearing in the model are evaluated at the following values: Age = 30.26, Man_dummyvariable = .3226, NonW_dummyvariable = .2581, Couple_nochild_dummyvariable = .3548, Household_other_dummyvariable = .3871, Baseline stress = 7.42, Baseline hedonic tone = 13.45, Baseline energy = 12.39, Loneliness = 34.48, Trait social connectedness = 91.81, Connectedness_to_nature_average = 3.5461.

Pairwise Comparisons^a

(I) Environment	(J) Environment	Mean Difference (I-J)	Std. Error	df	Sig. ^b	95% Confidence Interval for Difference ^b	
						Lower Bound	Upper Bound
no people	few people	-.129	.306	150.000	1.000	-.870	.612
	lots of people	.129	.306	150.000	1.000	-.612	.870
few people	no people	.129	.306	150.000	1.000	-.612	.870
	lots of people	.258	.306	150.000	1.000	-.483	.999
lots of people	no people	-.129	.306	150.000	1.000	-.870	.612
	few people	-.258	.306	150.000	1.000	-.999	.483

Based on estimated marginal means

a. Dependent Variable: Hedonic tone.

b. Adjustment for multiple comparisons: Bonferroni.

4. Timepoint * Environment

Estimates^a

Timepoint	Environment	Mean	Std. Error	df	95% Confidence Interval	
					Lower Bound	Upper Bound
Pre environment	no people	12.194 ^b	1.241	169	9.743	14.644
	few people	12.032 ^b	1.241	169	9.582	14.483
	lots of people	11.968 ^b	1.241	169	9.517	14.418
Post environment	no people	13.839 ^b	1.241	169	11.388	16.289
	few people	14.258 ^b	1.241	169	11.808	16.709
	lots of people	13.806 ^b	1.241	169	11.356	16.257

a. Dependent Variable: Hedonic tone.

b. Covariates appearing in the model are evaluated at the following values: Age = 30.26, Man_dummyvariable = .3226, NonW_dummyvariable = .2581, Couple_nochild_dummyvariable = .3548, Household_other_dummyvariable = .3871, Baseline stress = 7.42, Baseline hedonic tone = 13.45, Baseline energy = 12.39, Loneliness = 34.48, Trait social connectedness = 91.81, Connectedness_to_nature_average = 3.5461.

Pairwise Comparisons^a

Environment	(I) Timepoint	(J) Timepoint	Mean Difference (I-J)	Std. Error	df	Sig. ^c	95% Confidence Interval for Difference ^c	
							Lower Bound	Upper Bound
no people	Pre environment	Post environment	-1.645 [*]	.433	150.000	<.001	-2.501	-.790
	Post environment	Pre environment	1.645 [*]	.433	150.000	<.001	.790	2.501
few people	Pre environment	Post environment	-2.226 [*]	.433	150.000	<.001	-3.081	-1.370
	Post environment	Pre environment	2.226 [*]	.433	150.000	<.001	1.370	3.081
lots of people	Pre environment	Post environment	-1.839 [*]	.433	150.000	<.001	-2.694	-.983
	Post environment	Pre environment	1.839 [*]	.433	150.000	<.001	.983	2.694

Based on estimated marginal means

*. The mean difference is significant at the .05 level.

a. Dependent Variable: Hedonic tone.

c. Adjustment for multiple comparisons: Bonferroni.

Hedonic tone – middle to older adults

Information Criteria^a

-2 Restricted Log Likelihood	621.91245925
Akaike's Information Criterion (AIC)	627.91245925
Hurvich and Tsai's Criterion (AICC)	628.08267201
Bozdogan's Criterion (CAIC)	639.84266047
Schwarz's Bayesian Criterion (BIC)	636.84266047

The information criteria are displayed in smaller-is-better form.

a. Dependent Variable: Hedonic tone.

Fixed Effects

Type III Tests of Fixed Effects^a

Source	Numerator df	Denominator df	F	Sig.
Intercept	1	16.337	5.299	.035
Timepoint	1	128.590	47.277	<.001
Environment	2	128.587	2.833	.063
Timepoint * Environment	2	128.587	1.415	.247
Age	1	17.296	.055	.817
Man_dummyvariable	1	14.893	.160	.695
NonW_dummyvariable	1	15.650	.131	.723
Couple_nochild_dummyvariable	1	15.888	1.761	.203
Household_other_dummyvariable	1	14.932	.378	.548
Baseline_stress	1	15.663	10.113	.006
Baseline_hedonic_tone	1	129.951	.012	.913
Baseline_energy	1	15.101	.600	.451
Loneliness	1	15.186	.070	.796
Trait_social_connectedness	1	14.934	.196	.664
Connectedness_to_nature_average	1	15.429	.014	.907

a. Dependent Variable: Hedonic tone.

2. Timepoint

Estimates^a

Timepoint	Mean	Std. Error	df	95% Confidence Interval	
				Lower Bound	Upper Bound
Pre environment	12.789 ^b	1.062	145	10.690	14.888
Post environment	14.334 ^b	1.062	145	12.235	16.433

a. Dependent Variable: Hedonic tone.

b. Covariates appearing in the model are evaluated at the following values: Age = 47.63, Man_dummyvariable = .2963, NonW_dummyvariable = .1111, Couple_nochild_dummyvariable = .2222, Household_other_dummyvariable = .3333, Baseline stress = 7.56, Baseline hedonic tone = 13.98, Baseline energy = 11.81, Loneliness = 34.04, Trait social connectedness = 92.41, Connectedness_to_nature_average = 3.7487.

Pairwise Comparisons^a

(I) Timepoint	(J) Timepoint	Mean Difference (I-J)	Std. Error	df	Sig. ^c	95% Confidence Interval for Difference ^c	
						Lower Bound	Upper Bound
Pre environment	Post environment	-1.545 [*]	.225	128.590	<.001	-1.990	-1.100
Post environment	Pre environment	1.545 [*]	.225	128.590	<.001	1.100	1.990

Based on estimated marginal means

*. The mean difference is significant at the .05 level.

a. Dependent Variable: Hedonic tone.

c. Adjustment for multiple comparisons: Bonferroni.

3. Environment

Estimates^a

Environment	Mean	Std. Error	df	95% Confidence Interval	
				Lower Bound	Upper Bound
no people	13.743 ^b	1.068	145	11.632	15.854
few people	13.758 ^b	1.068	145	11.648	15.869
lots of people	13.184 ^b	1.068	145	11.074	15.295

a. Dependent Variable: Hedonic tone.

b. Covariates appearing in the model are evaluated at the following values: Age = 47.63, Man_dummyvariable = .2963, NonW_dummyvariable = .1111, Couple_nochild_dummyvariable = .2222, Household_other_dummyvariable = .3333, Baseline stress = 7.56, Baseline hedonic tone = 13.98, Baseline energy = 11.81, Loneliness = 34.04, Trait social connectedness = 92.41, Connectedness_to_nature_average = 3.7487.

Pairwise Comparisons^a

(I) Environment	(J) Environment	Mean Difference (I-J)	Std. Error	df	Sig. ^b	95% Confidence Interval for Difference ^b	
						Lower Bound	Upper Bound
no people	few people	-.016	.276	128.761	1.000	-.684	.653
	lots of people	.558	.276	128.761	.135	-.110	1.227
few people	no people	.016	.276	128.761	1.000	-.653	.684
	lots of people	.574	.274	128.244	.115	-.092	1.240
lots of people	no people	-.558	.276	128.761	.135	-1.227	.110
	few people	-.574	.274	128.244	.115	-1.240	.092

Based on estimated marginal means

a. Dependent Variable: Hedonic tone.

b. Adjustment for multiple comparisons: Bonferroni.

4. Timepoint * Environment

Estimates^a

Timepoint	Environment	Mean	Std. Error	df	95% Confidence Interval	
					Lower Bound	Upper Bound
Pre environment	no people	13.184 ^b	1.085	145	11.039	15.330
	few people	12.740 ^b	1.085	145	10.595	14.885
	lots of people	12.443 ^b	1.085	145	10.298	14.589
Post environment	no people	14.301 ^b	1.086	145	12.154	16.448
	few people	14.777 ^b	1.085	145	12.632	16.922
	lots of people	13.925 ^b	1.085	145	11.780	16.070

a. Dependent Variable: Hedonic tone.

b. Covariates appearing in the model are evaluated at the following values: Age = 47.63, Man_dummyvariable = .2963, NonW_dummyvariable = .1111, Couple_nochild_dummyvariable = .2222, Household_other_dummyvariable = .3333, Baseline stress = 7.56, Baseline hedonic tone = 13.98, Baseline energy = 11.81, Loneliness = 34.04, Trait social connectedness = 92.41, Connectedness_to_nature_average = 3.7487.

Pairwise Comparisons^a

Environment	(I) Timepoint	(J) Timepoint	Mean Difference (I-J)	Std. Error	df	Sig. ^c	95% Confidence Interval for Difference ^c	
							Lower Bound	Upper Bound
no people	Pre environment	Post environment	-1.117 [*]	.392	129.263	.005	-1.892	-.342
	Post environment	Pre environment	1.117 [*]	.392	129.263	.005	.342	1.892
few people	Pre environment	Post environment	-2.037 [*]	.388	128.244	<.001	-2.805	-1.269
	Post environment	Pre environment	2.037 [*]	.388	128.244	<.001	1.269	2.805
lots of people	Pre environment	Post environment	-1.481 [*]	.388	128.244	<.001	-2.249	-.714
	Post environment	Pre environment	1.481 [*]	.388	128.244	<.001	.714	2.249

Based on estimated marginal means

*. The mean difference is significant at the .05 level.

a. Dependent Variable: Hedonic tone.

c. Adjustment for multiple comparisons: Bonferroni.

Energy – younger adults (18-24 yrs)

Information Criteria^a

-2 Restricted Log Likelihood	794.59406599
Akaike's Information Criterion (AIC)	800.59406599
Hurvich and Tsai's Criterion (AICC)	800.73952053
Bozdogan's Criterion (CAIC)	812.98376213
Schwarz's Bayesian Criterion (BIC)	809.98376213

The information criteria are displayed in smaller-is-better form.

a. Dependent Variable: Energy.

Fixed Effects

Type III Tests of Fixed Effects^a

Source	Numerator df	Denominator df	F	Sig.
Intercept	1	19.800	4.652	.043
Timepoint	1	150	36.476	<.001
Environment	2	150	.426	.654
Timepoint * Environment	2	150	1.707	.185
Age	1	19.023	.369	.551
Man_dummyvariable	1	19.023	.034	.856
NonW_dummyvariable	1	19.023	1.625	.218
Couple_nochild_dummyvariable	1	19.023	.593	.451
Household_other_dummyvariable	1	19.023	.870	.363
Baseline_stress	1	19.023	1.026	.324
Baseline_hedonic_tone	1	19.023	.001	.982
Baseline_energy	1	19.023	1.001	.330
Loneliness	1	19.023	3.717	.069
Trait_social_connectedness	1	19.023	.433	.519
Connectedness_to_nature_average	1	19.023	1.000	.330

a. Dependent Variable: Energy.

2. Timepoint

Estimates^a

Timepoint	Mean	Std. Error	df	95% Confidence Interval	
				Lower Bound	Upper Bound
Pre environment	10.161 ^b	1.318	169	7.559	12.764
Post environment	11.763 ^b	1.318	169	9.161	14.366

a. Dependent Variable: Energy.

b. Covariates appearing in the model are evaluated at the following values: Age = 30.26, Man_dummyvariable = .3226, NonW_dummyvariable = .2581, Couple_nochild_dummyvariable = .3548, Household_other_dummyvariable = .3871, Baseline stress = 7.42, Baseline hedonic tone = 13.45, Baseline energy = 12.39, Loneliness = 34.48, Trait social connectedness = 91.81, Connectedness_to_nature_average = 3.5461.

Pairwise Comparisons^a

(I) Timepoint	(J) Timepoint	Mean Difference (I-J)	Std. Error	df	Sig. ^c	95% Confidence Interval for Difference ^c	
						Lower Bound	Upper Bound
Pre environment	Post environment	-1.602 [*]	.265	150	<.001	-2.126	-1.078
Post environment	Pre environment	1.602 [*]	.265	150	<.001	1.078	2.126

Based on estimated marginal means

*. The mean difference is significant at the .05 level.

a. Dependent Variable: Energy.

c. Adjustment for multiple comparisons: Bonferroni.

3. Environment

Estimates^a

Environment	Mean	Std. Error	df	95% Confidence Interval	
				Lower Bound	Upper Bound
no people	11.065 ^b	1.325	169	8.449	13.680
few people	10.790 ^b	1.325	169	8.174	13.406
lots of people	11.032 ^b	1.325	169	8.416	13.648

a. Dependent Variable: Energy.

b. Covariates appearing in the model are evaluated at the following values: Age = 30.26, Man_dummyvariable = .3226, NonW_dummyvariable = .2581, Couple_nochild_dummyvariable = .3548, Household_other_dummyvariable = .3871, Baseline stress = 7.42, Baseline hedonic tone = 13.45, Baseline energy = 12.39, Loneliness = 34.48, Trait social connectedness = 91.81, Connectedness_to_nature_average = 3.5461.

Pairwise Comparisons^a

(I) Environment	(J) Environment	Mean Difference (I-J)	Std. Error	df	Sig. ^b	95% Confidence Interval for Difference ^b	
						Lower Bound	Upper Bound
no people	few people	.274	.325	150	1.000	-.512	1.061
	lots of people	.032	.325	150	1.000	-.754	.819
few people	no people	-.274	.325	150	1.000	-1.061	.512
	lots of people	-.242	.325	150	1.000	-1.029	.545
lots of people	no people	-.032	.325	150	1.000	-.819	.754
	few people	.242	.325	150	1.000	-.545	1.029

Based on estimated marginal means

a. Dependent Variable: Energy.

b. Adjustment for multiple comparisons: Bonferroni.

4. Timepoint * Environment

Estimates^a

Timepoint	Environment	Mean	Std. Error	df	95% Confidence Interval	
					Lower Bound	Upper Bound
Pre environment	no people	10.581 ^b	1.345	169	7.926	13.236
	few people	9.710 ^b	1.345	169	7.055	12.365
	lots of people	10.194 ^b	1.345	169	7.539	12.848
Post environment	no people	11.548 ^b	1.345	169	8.894	14.203
	few people	11.871 ^b	1.345	169	9.216	14.526
	lots of people	11.871 ^b	1.345	169	9.216	14.526

a. Dependent Variable: Energy.

b. Covariates appearing in the model are evaluated at the following values: Age = 30.26, Man_dummyvariable = .3226, NonW_dummyvariable = .2581, Couple_nochild_dummyvariable = .3548, Household_other_dummyvariable = .3871, Baseline stress = 7.42, Baseline hedonic tone = 13.45, Baseline energy = 12.39, Loneliness = 34.48, Trait social connectedness = 91.81, Connectedness_to_nature_average = 3.5461.

Pairwise Comparisons^a

Environment	(I) Timepoint	(J) Timepoint	Mean Difference (I-J)	Std. Error	df	Sig. ^c	95% Confidence Interval for Difference ^c	
							Lower Bound	Upper Bound
no people	Pre environment	Post environment	-.968 [*]	.459	150	.037	-1.876	-.060
	Post environment	Pre environment	.968 [*]	.459	150	.037	.060	1.876
few people	Pre environment	Post environment	-2.161 [*]	.459	150	<.001	-3.069	-1.253
	Post environment	Pre environment	2.161 [*]	.459	150	<.001	1.253	3.069
lots of people	Pre environment	Post environment	-1.677 [*]	.459	150	<.001	-2.585	-.770
	Post environment	Pre environment	1.677 [*]	.459	150	<.001	.770	2.585

Based on estimated marginal means

*. The mean difference is significant at the .05 level.

a. Dependent Variable: Energy.

c. Adjustment for multiple comparisons: Bonferroni.

Energy – middle to older adults

Information Criteria^a

-2 Restricted Log Likelihood	664.61013182
Akaike's Information Criterion (AIC)	670.61013182
Hurvich and Tsai's Criterion (AICC)	670.78034459
Bozdogan's Criterion (CAIC)	682.54033305
Schwarz's Bayesian Criterion (BIC)	679.54033305

The information criteria are displayed in smaller-is-better form.

a. Dependent Variable: Energy.

Fixed Effects

Type III Tests of Fixed Effects^a

Source	Numerator df	Denominator df	F	Sig.
Intercept	1	17.556	1.076	.314
Timepoint	1	129.673	31.696	<.001
Environment	2	129.670	.778	.462
Timepoint * Environment	2	129.670	3.313	.040
Age	1	18.656	.575	.458
Man_dummyvariable	1	15.825	.020	.890
NonW_dummyvariable	1	16.720	.642	.434
Couple_nochild_dummyvariable	1	17.001	1.955	.180
Household_other_dummyvariable	1	15.871	.576	.459
Baseline_stress	1	16.735	4.759	.044
Baseline_hedonic_tone	1	120.360	1.359	.246
Baseline_energy	1	16.071	5.778	.029
Loneliness	1	16.171	.046	.832
Trait_social_connectedness	1	15.874	.566	.463
Connectedness_to_nature_average	1	16.459	1.495	.239

a. Dependent Variable: Energy.

2. Timepoint

Estimates^a

Timepoint	Mean	Std. Error	df	95% Confidence Interval	
				Lower Bound	Upper Bound
Pre environment	10.456 ^b	1.209	145	8.067	12.845
Post environment	11.939 ^b	1.209	145	9.550	14.328

a. Dependent Variable: Energy.

b. Covariates appearing in the model are evaluated at the following values: Age = 47.63, Man_dummyvariable = .2963, NonW_dummyvariable = .1111, Couple_nochild_dummyvariable = .2222, Household_other_dummyvariable = .3333, Baseline stress = 7.56, Baseline hedonic tone = 13.98, Baseline energy = 11.81, Loneliness = 34.04, Trait social connectedness = 92.41, Connectedness_to_nature_average = 3.7487.

Pairwise Comparisons^a

(I) Timepoint	(J) Timepoint	Mean Difference (I-J)	Std. Error	df	Sig. ^c	95% Confidence Interval for Difference ^c	
						Lower Bound	Upper Bound
Pre environment	Post environment	-1.483 [*]	.263	129.673	<.001	-2.004	-.962
Post environment	Pre environment	1.483 [*]	.263	129.673	<.001	.962	2.004

Based on estimated marginal means

*. The mean difference is significant at the .05 level.

a. Dependent Variable: Energy.

c. Adjustment for multiple comparisons: Bonferroni.

3. Environment

Estimates^a

Environment	Mean	Std. Error	df	95% Confidence Interval	
				Lower Bound	Upper Bound
no people	11.366 ^b	1.216	145	8.962	13.769
few people	11.252 ^b	1.216	145	8.849	13.656
lots of people	10.975 ^b	1.216	145	8.571	13.378

a. Dependent Variable: Energy.

b. Covariates appearing in the model are evaluated at the following values: Age = 47.63, Man_dummyvariable = .2963, NonW_dummyvariable = .1111, Couple_nochild_dummyvariable = .2222, Household_other_dummyvariable = .3333, Baseline stress = 7.56, Baseline hedonic tone = 13.98, Baseline energy = 11.81, Loneliness = 34.04, Trait social connectedness = 92.41, Connectedness_to_nature_average = 3.7487.

Pairwise Comparisons^a

(I) Environment	(J) Environment	Mean Difference (I-J)	Std. Error	df	Sig. ^b	95% Confidence Interval for Difference ^b	
						Lower Bound	Upper Bound
no people	few people	.113	.323	129.854	1.000	-.670	.897
	lots of people	.391	.323	129.854	.685	-.393	1.175
few people	no people	-.113	.323	129.854	1.000	-.897	.670
	lots of people	.278	.322	129.305	1.000	-.502	1.058
lots of people	no people	-.391	.323	129.854	.685	-1.175	.393
	few people	-.278	.322	129.305	1.000	-1.058	.502

Based on estimated marginal means

a. Dependent Variable: Energy.

b. Adjustment for multiple comparisons: Bonferroni.

4. Timepoint * Environment

Estimates^a

Timepoint	Environment	Mean	Std. Error	df	95% Confidence Interval	
					Lower Bound	Upper Bound
Pre environment	no people	11.049 ^b	1.237	145	8.604	13.494
	few people	10.493 ^b	1.237	145	8.048	12.938
	lots of people	9.826 ^b	1.237	145	7.381	12.272
Post environment	no people	11.683 ^b	1.238	145	9.236	14.130
	few people	12.012 ^b	1.237	145	9.567	14.457
	lots of people	12.123 ^b	1.237	145	9.678	14.568

a. Dependent Variable: Energy.

b. Covariates appearing in the model are evaluated at the following values: Age = 47.63, Man_dummyvariable = .2963, NonW_dummyvariable = .1111, Couple_nochild_dummyvariable = .2222, Household_other_dummyvariable = .3333, Baseline stress = 7.56, Baseline hedonic tone = 13.98, Baseline energy = 11.81, Loneliness = 34.04, Trait social connectedness = 92.41, Connectedness_to_nature_average = 3.7487.

Pairwise Comparisons^a

Environment	(I) Timepoint	(J) Timepoint	Mean Difference (I-J)	Std. Error	df	Sig. ^c	95% Confidence Interval for Difference ^c	
							Lower Bound	Upper Bound
no people	Pre environment	Post environment	-.634	.459	130.388	.169	-1.542	.274
	Post environment	Pre environment	.634	.459	130.388	.169	-.274	1.542
few people	Pre environment	Post environment	-1.519 [*]	.455	129.305	.001	-2.419	-.618
	Post environment	Pre environment	1.519 [*]	.455	129.305	.001	.618	2.419
lots of people	Pre environment	Post environment	-2.296 [*]	.455	129.305	<.001	-3.196	-1.396
	Post environment	Pre environment	2.296 [*]	.455	129.305	<.001	1.396	3.196

Based on estimated marginal means

*. The mean difference is significant at the .05 level.

a. Dependent Variable: Energy.

c. Adjustment for multiple comparisons: Bonferroni

Perceived restorativeness – younger adults (18-24 yrs)

Information Criteria^a

-2 Restricted Log Likelihood	661.57193193
Akaike's Information Criterion (AIC)	667.57193193
Hurvich and Tsai's Criterion (AICC)	667.71738648
Bozdogan's Criterion (CAIC)	679.96162808
Schwarz's Bayesian Criterion (BIC)	676.96162808

The information criteria are displayed in smaller-is-better form.

a. Dependent Variable: Perceived restorativeness.

Fixed Effects

Type III Tests of Fixed Effects^a

Source	Numerator df	Denominator df	F	Sig.
Intercept	1	19.833	.001	.970
Timepoint	1	150	410.744	<.001
Environment	2	150	8.450	<.001
Timepoint * Environment	2	150	5.263	.006
Age	1	19.021	4.614	.045
Man_dummyvariable	1	19.021	1.018	.326
NonW_dummyvariable	1	19.021	1.271	.274
Couple_nochild_dummyvariable	1	19.021	1.961	.178
Household_other_dummyvariable	1	19.021	1.115	.304
Baseline_stress	1	19.021	.768	.392
Baseline_hedonic_tone	1	19.021	.006	.941
Baseline_energy	1	19.021	.002	.961
Loneliness	1	19.021	.000	.984
Trait_social_connectedness	1	19.021	.662	.426
Connectedness_to_nature_average	1	19.021	.191	.667

a. Dependent Variable: Perceived restorativeness.

2. Timepoint

Estimates^a

Timepoint	Mean	Std. Error	df	95% Confidence Interval	
				Lower Bound	Upper Bound
Pre environment	1.587 ^b	.881	169	-.153	3.327
Post environment	5.228 ^b	.881	169	3.488	6.968

a. Dependent Variable: Perceived restorativeness.

b. Covariates appearing in the model are evaluated at the following values: Age = 30.26, Man_dummyvariable = .3226, NonW_dummyvariable = .2581, Couple_nochild_dummyvariable = .3548, Household_other_dummyvariable = .3871, Baseline stress = 7.42, Baseline hedonic tone = 13.45, Baseline energy = 12.39, Loneliness = 34.48, Trait social connectedness = 91.81, Connectedness_to_nature_average = 3.5461.

Pairwise Comparisons^a

(I) Timepoint	(J) Timepoint	Mean Difference (I-J)	Std. Error	df	Sig. ^c	95% Confidence Interval for Difference ^c	
						Lower Bound	Upper Bound
Pre environment	Post environment	-3.641 [*]	.180	150	<.001	-3.996	-3.286
Post environment	Pre environment	3.641 [*]	.180	150	<.001	3.286	3.996

Based on estimated marginal means

*. The mean difference is significant at the .05 level.

a. Dependent Variable: Perceived restorativeness.

c. Adjustment for multiple comparisons: Bonferroni.

3. Environment

Estimates^a

Environment	Mean	Std. Error	df	95% Confidence Interval	
				Lower Bound	Upper Bound
no people	3.845 ^b	.886	169	2.096	5.594
few people	3.435 ^b	.886	169	1.686	5.185
lots of people	2.942 ^b	.886	169	1.193	4.691

a. Dependent Variable: Perceived restorativeness.

b. Covariates appearing in the model are evaluated at the following values: Age = 30.26, Man_dummyvariable = .3226, NonW_dummyvariable = .2581, Couple_nochild_dummyvariable = .3548, Household_other_dummyvariable = .3871, Baseline stress = 7.42, Baseline hedonic tone = 13.45, Baseline energy = 12.39, Loneliness = 34.48, Trait social connectedness = 91.81, Connectedness_to_nature_average = 3.5461.

Pairwise Comparisons^a

(I) Environment	(J) Environment	Mean Difference (I-J)	Std. Error	df	Sig. ^c	95% Confidence Interval for Difference ^c	
						Lower Bound	Upper Bound
no people	few people	.410	.220	150	.194	-.123	.942
	lots of people	.903 [*]	.220	150	<.001	.371	1.436
few people	no people	-.410	.220	150	.194	-.942	.123
	lots of people	.494	.220	150	.079	-.039	1.026
lots of people	no people	-.903 [*]	.220	150	<.001	-1.436	-.371
	few people	-.494	.220	150	.079	-1.026	.039

Based on estimated marginal means

*. The mean difference is significant at the .05 level.

a. Dependent Variable: Perceived restorativeness.

c. Adjustment for multiple comparisons: Bonferroni.

4. Timepoint * Environment

Estimates^a

Timepoint	Environment	Mean	Std. Error	df	95% Confidence Interval	
					Lower Bound	Upper Bound
Pre environment	no people	1.768 ^b	.900	169	-.008	3.544
	few people	1.465 ^b	.900	169	-.311	3.240
	lots of people	1.529 ^b	.900	169	-.247	3.305
Post environment	no people	5.923 ^b	.900	169	4.147	7.698
	few people	5.406 ^b	.900	169	3.631	7.182
	lots of people	4.355 ^b	.900	169	2.579	6.131

a. Dependent Variable: Perceived restorativeness.

b. Covariates appearing in the model are evaluated at the following values: Age = 30.26, Man_dummyvariable = .3226, NonW_dummyvariable = .2581, Couple_nochild_dummyvariable = .3548, Household_other_dummyvariable = .3871, Baseline stress = 7.42, Baseline hedonic tone = 13.45, Baseline energy = 12.39, Loneliness = 34.48, Trait social connectedness = 91.81, Connectedness_to_nature_average = 3.5461.

Pairwise Comparisons^a

Environment	(I) Timepoint	(J) Timepoint	Mean Difference (I-J)	Std. Error	df	Sig. ^c	95% Confidence Interval for Difference ^c	
							Lower Bound	Upper Bound
no people	Pre environment	Post environment	-4.155 [*]	.311	150	<.001	-4.770	-3.540
	Post environment	Pre environment	4.155 [*]	.311	150	<.001	3.540	4.770
few people	Pre environment	Post environment	-3.942 [*]	.311	150	<.001	-4.557	-3.327
	Post environment	Pre environment	3.942 [*]	.311	150	<.001	3.327	4.557
lots of people	Pre environment	Post environment	-2.826 [*]	.311	150	<.001	-3.441	-2.211
	Post environment	Pre environment	2.826 [*]	.311	150	<.001	2.211	3.441

Based on estimated marginal means

*. The mean difference is significant at the .05 level.

a. Dependent Variable: Perceived restorativeness.

c. Adjustment for multiple comparisons: Bonferroni.

Perceived restorativeness – middle to older adults

Information Criteria^a

-2 Restricted Log Likelihood	614.71840481
Akaike's Information Criterion (AIC)	620.71840481
Hurvich and Tsai's Criterion (AICC)	620.88861757
Bozdogan's Criterion (CAIC)	632.64860604
Schwarz's Bayesian Criterion (BIC)	629.64860604

The information criteria are displayed in smaller-is-better form.

a. Dependent Variable: Perceived restorativeness.

Fixed Effects

Type III Tests of Fixed Effects^a

Source	Numerator df	Denominator df	F	Sig.
Intercept	1	17.822	1.608	.221
Timepoint	1	129.798	365.547	<.001
Environment	2	129.795	4.723	.010
Timepoint * Environment	2	129.795	3.978	.021
Age	1	19.012	1.796	.196
Man_dummyvariable	1	15.706	.044	.837
NonW_dummyvariable	1	16.764	.132	.721
Couple_nochild_dummyvariable	1	17.095	.157	.697
Household_other_dummyvariable	1	15.760	.063	.805
Baseline_stress	1	16.783	1.611	.222
Baseline_hedonic_tone	1	92.914	.025	.876
Baseline_energy	1	15.998	2.013	.175
Loneliness	1	16.117	.001	.979
Trait_social_connectedness	1	15.764	.125	.728
Connectedness_to_nature_average	1	16.457	.947	.345

a. Dependent Variable: Perceived restorativeness.

2. Timepoint

Estimates^a

Timepoint	Mean	Std. Error	df	95% Confidence Interval	
				Lower Bound	Upper Bound
Pre environment	1.201 ^b	.971	145	-.718	3.120
Post environment	5.542 ^b	.971	145	3.623	7.461

a. Dependent Variable: Perceived restorativeness.

b. Covariates appearing in the model are evaluated at the following values: Age = 47.63, Man_dummyvariable = .2963, NonW_dummyvariable = .1111, Couple_nochild_dummyvariable = .2222, Household_other_dummyvariable = .3333, Baseline stress = 7.56, Baseline hedonic tone = 13.98, Baseline energy = 11.81, Loneliness = 34.04, Trait social connectedness = 92.41, Connectedness_to_nature_average = 3.7487.

Pairwise Comparisons^a

(I) Timepoint	(J) Timepoint	Mean Difference (I-J)	Std. Error	df	Sig. ^c	95% Confidence Interval for Difference ^c	
						Lower Bound	Upper Bound
Pre environment	Post environment	-4.341 [*]	.227	129.798	<.001	-4.790	-3.892
Post environment	Pre environment	4.341 [*]	.227	129.798	<.001	3.892	4.790

Based on estimated marginal means

*. The mean difference is significant at the .05 level.

a. Dependent Variable: Perceived restorativeness.

c. Adjustment for multiple comparisons: Bonferroni.

3. Environment

Estimates^a

Environment	Mean	Std. Error	df	95% Confidence Interval	
				Lower Bound	Upper Bound
no people	3.672 ^b	.978	145	1.739	5.604
few people	3.561 ^b	.978	145	1.629	5.493
lots of people	2.883 ^b	.978	145	.951	4.815

a. Dependent Variable: Perceived restorativeness.

b. Covariates appearing in the model are evaluated at the following values: Age = 47.63, Man_dummyvariable = .2963, NonW_dummyvariable = .1111, Couple_nochild_dummyvariable = .2222, Household_other_dummyvariable = .3333, Baseline stress = 7.56, Baseline hedonic tone = 13.98, Baseline energy = 11.81, Loneliness = 34.04, Trait social connectedness = 92.41, Connectedness_to_nature_average = 3.7487.

Pairwise Comparisons^a

(I) Environment	(J) Environment	Mean Difference (I-J)	Std. Error	df	Sig. ^c	95% Confidence Interval for Difference ^c	
						Lower Bound	Upper Bound
no people	few people	.111	.278	130.016	1.000	-.564	.786
	lots of people	.789 [*]	.278	130.016	.016	.114	1.464
few people	no people	-.111	.278	130.016	1.000	-.786	.564
	lots of people	.678 [*]	.277	129.356	.048	.005	1.351
lots of people	no people	-.789 [*]	.278	130.016	.016	-1.464	-.114
	few people	-.678 [*]	.277	129.356	.048	-1.351	-.005

Based on estimated marginal means

*. The mean difference is significant at the .05 level.

a. Dependent Variable: Perceived restorativeness.

c. Adjustment for multiple comparisons: Bonferroni

4. Timepoint * Environment

Estimates^a

Timepoint	Environment	Mean	Std. Error	df	95% Confidence Interval	
					Lower Bound	Upper Bound
Pre environment	no people	1.290 ^b	.997	145	-.680	3.261
	few people	1.149 ^b	.997	145	-.821	3.120
	lots of people	1.164 ^b	.997	145	-.806	3.135
Post environment	no people	6.053 ^b	.998	145	4.081	8.025
	few people	5.972 ^b	.997	145	4.001	7.942
	lots of people	4.601 ^b	.997	145	2.631	6.572

a. Dependent Variable: Perceived restorativeness.

b. Covariates appearing in the model are evaluated at the following values: Age = 47.63, Man_dummyvariable = .2963, NonW_dummyvariable = .1111, Couple_nochild_dummyvariable = .2222, Household_other_dummyvariable = .3333, Baseline stress = 7.56, Baseline hedonic tone = 13.98, Baseline energy = 11.81, Loneliness = 34.04, Trait social connectedness = 92.41, Connectedness_to_nature_average = 3.7487.

Pairwise Comparisons^a

Environment	(I) Timepoint	(J) Timepoint	Mean Difference (I-J)	Std. Error	df	Sig. ^c	95% Confidence Interval for Difference ^c	
							Lower Bound	Upper Bound
no people	Pre environment	Post environment	-4.763 [*]	.395	130.658	<.001	-5.545	-3.981
	Post environment	Pre environment	4.763 [*]	.395	130.658	<.001	3.981	5.545
few people	Pre environment	Post environment	-4.822 [*]	.392	129.356	<.001	-5.598	-4.046
	Post environment	Pre environment	4.822 [*]	.392	129.356	<.001	4.046	5.598
lots of people	Pre environment	Post environment	-3.437 [*]	.392	129.356	<.001	-4.213	-2.661
	Post environment	Pre environment	3.437 [*]	.392	129.356	<.001	2.661	4.213

Based on estimated marginal means

*. The mean difference is significant at the .05 level.

a. Dependent Variable: Perceived restorativeness.

c. Adjustment for multiple comparisons: Bonferroni.

State social connectedness - younger adults (18-24 yrs)

Information Criteria^a

-2 Restricted Log Likelihood	611.65550806
Akaike's Information Criterion (AIC)	617.65550806
Hurvich and Tsai's Criterion (AICC)	617.97550806
Bozdogan's Criterion (CAIC)	627.76385162
Schwarz's Bayesian Criterion (BIC)	624.76385162

The information criteria are displayed in smaller-is-better form.

a. Dependent Variable: State social connectedness.

Fixed Effects

Type III Tests of Fixed Effects^a

Source	Numerator df	Denominator df	F	Sig.
Intercept	1	79	.230	.633
Timepoint	0	.	.	.
Environment	2	79	9.858	<.001
Timepoint* Environment	0	.	.	.
Age	1	79	10.571	.002
Man_dummyvariable	1	79	.933	.337
NonW_dummyvariable	1	79	.516	.475
Couple_nochild_dummyvariable	1	79	.006	.939
Household_other_dummyvariable	1	79	3.259	.075
Baseline_stress	1	79	.036	.849
Baseline_hedonic_tone	1	79	1.864	.176
Baseline_energy	1	79	.103	.749
Loneliness	1	79	.022	.882
Trait_social_connectedness	1	79	.136	.713
Connectedness_to_nature_average	1	79	7.953	.006

a. Dependent Variable: State social connectedness.

3. Environment

Estimates^a

Environment	Mean	Std. Error	df	95% Confidence Interval	
				Lower Bound	Upper Bound
no people	42.774 ^b	4.808	79	33.205	52.344
few people	50.581 ^b	4.808	79	41.011	60.150
lots of people	49.903 ^b	4.808	79	40.334	59.473

a. Dependent Variable: State social connectedness.

b. Covariates appearing in the model are evaluated at the following values: Age = 30.26, Man_dummyvariable = .3226, NonW_dummyvariable = .2581, Couple_nochild_dummyvariable = .3548, Household_other_dummyvariable = .3871, Baseline stress = 7.42, Baseline hedonic tone = 13.45, Baseline energy = 12.39, Loneliness = 34.48, Trait social connectedness = 91.81, Connectedness_to_nature_average = 3.5461.

Pairwise Comparisons^a

(I) Environment	(J) Environment	Mean Difference (I-J)	Std. Error	df	Sig. ^c	95% Confidence Interval for Difference ^c	
						Lower Bound	Upper Bound
no people	few people	-7.806 [*]	1.948	79	<.001	-12.571	-3.042
	lots of people	-7.129 [*]	1.948	79	.001	-11.894	-2.364
few people	no people	7.806 [*]	1.948	79	<.001	3.042	12.571
	lots of people	.677	1.948	79	1.000	-4.087	5.442
lots of people	no people	7.129 [*]	1.948	79	.001	2.364	11.894
	few people	-.677	1.948	79	1.000	-5.442	4.087

Based on estimated marginal means

*. The mean difference is significant at the .05 level.

a. Dependent Variable: State social connectedness.

c. Adjustment for multiple comparisons: Bonferroni.

State social connectedness – middle to older adults

Information Criteria^a

-2 Restricted Log Likelihood	537.63631181
Akaike's Information Criterion (AIC)	543.63631181
Hurvich and Tsai's Criterion (AICC)	544.01726419
Bozdogan's Criterion (CAIC)	553.25038967
Schwarz's Bayesian Criterion (BIC)	550.25038967

The information criteria are displayed in smaller-is-better form.

a. Dependent Variable: State social connectedness.

Fixed Effects

Type III Tests of Fixed Effects^a

Source	Numerator df	Denominator df	F	Sig.
Intercept	1	17.152	.008	.929
Timepoint	0	.	.	.
Environment	2	51.745	5.899	.005
Timepoint * Environment	0	.	.	.
Age	1	18.837	.996	.331
Man_dummyvariable	1	15.871	.036	.853
NonW_dummyvariable	1	16.838	.763	.395
Couple_nochild_dummyvariable	1	17.065	.061	.808
Household_other_dummyvariable	1	16.067	.001	.971
Baseline_stress	1	16.548	.434	.519
Baseline_hedonic_tone	1	66.674	1.368	.246
Baseline_energy	1	16.212	.041	.841
Loneliness	1	16.138	.000	.985
Trait_social_connectedness	1	15.868	.812	.381
Connectedness_to_nature_average	1	16.448	5.106	.038

a. Dependent Variable: State social connectedness.

3. Environment

Estimates^a

Environment	Mean	Std. Error	df	95% Confidence Interval	
				Lower Bound	Upper Bound
no people	42.737 ^b	5.725	67	31.311	54.164
few people	49.594 ^b	5.722	67	38.173	61.016
lots of people	46.891 ^b	5.722	67	35.469	58.312

a. Dependent Variable: State social connectedness.

b. Covariates appearing in the model are evaluated at the following values: Age = 47.63, Man_dummyvariable = .2963, NonW_dummyvariable = .1111, Couple_nochild_dummyvariable = .2222, Household_other_dummyvariable = .3333, Baseline stress = 7.56, Baseline hedonic tone = 13.91, Baseline energy = 11.81, Loneliness = 34.04, Trait social connectedness = 92.41, Connectedness_to_nature_average = 3.7487.

Pairwise Comparisons^a

(I) Environment	(J) Environment	Mean Difference (I-J)	Std. Error	df	Sig. ^c	95% Confidence Interval for Difference ^c	
						Lower Bound	Upper Bound
no people	few people	-6.857 [*]	2.008	51.935	.004	-11.826	-1.888
	lots of people	-4.153	2.008	51.935	.131	-9.122	.816
few people	no people	6.857 [*]	2.008	51.935	.004	1.888	11.826
	lots of people	2.704	1.988	51.374	.539	-2.215	7.623
lots of people	no people	4.153	2.008	51.935	.131	-.816	9.122
	few people	-2.704	1.988	51.374	.539	-7.623	2.215

Based on estimated marginal means

*. The mean difference is significant at the .05 level.

a. Dependent Variable: State social connectedness.

c. Adjustment for multiple comparisons: Bonferroni.

Heart rate – younger adults (18-24 yrs)

Information Criteria^a

-2 Restricted Log Likelihood	1086.3102129
Akaike's Information Criterion (AIC)	1092.3102129
Hurvich and Tsai's Criterion (AICC)	1092.4681076
Bozdogan's Criterion (CAIC)	1104.4597809
Schwarz's Bayesian Criterion (BIC)	1101.4597809

The information criteria are displayed in smaller-is-better form.

a. Dependent Variable: Resting heart rate.

Fixed Effects

Type III Tests of Fixed Effects^a

Source	Numerator df	Denominator df	F	Sig.
Intercept	1	19.116	.018	.895
Timepoint	1	137.180	.489	.486
Environment	2	137.046	.842	.433
Timepoint * Environment	2	137.046	1.898	.154
Age	1	18.962	.323	.577
Man_dummyvariable	1	19.057	1.799	.196
NonW_dummyvariable	1	19.429	4.540	.046
Couple_nochild_dummyvariable	1	19.426	.101	.755
Household_other_dummyvariable	1	18.734	.091	.767
Baseline_stress	1	18.986	.104	.751
Baseline_hedonic_tone	1	18.728	2.382	.139
Baseline_energy	1	18.812	4.158	.056
Loneliness	1	18.912	1.063	.316
Trait_social_connectedness	1	18.713	.269	.610
Connectedness_to_nature_average	1	19.191	.009	.924

a. Dependent Variable: Resting heart rate.

2. Timepoint

Estimates^a

Timepoint	Mean	Std. Error	df	95% Confidence Interval	
				Lower Bound	Upper Bound
Pre environment	73.957 ^b	7.447	156	59.248	88.666
Post environment	73.440 ^b	7.449	156	58.726	88.154

a. Dependent Variable: Resting heart rate.

b. Covariates appearing in the model are evaluated at the following values: Age = 30.17, Man_dummyvariable = .2717, NonW_dummyvariable = .2486, Couple_nochild_dummyvariable = .3353, Household_other_dummyvariable = .3873, Baseline stress = 7.55, Baseline hedonic tone = 13.36, Baseline energy = 12.23, Loneliness = 34.40, Trait social connectedness = 92.13, Connectedness_to_nature_average = 3.5628.

Pairwise Comparisons^a

(I) Timepoint	(J) Timepoint	Mean Difference (I-J)	Std. Error	df	Sig. ^b	95% Confidence Interval for Difference ^b	
						Lower Bound	Upper Bound
Pre environment	Post environment	.517	.739	137.180	.486	-.945	1.978
Post environment	Pre environment	-.517	.739	137.180	.486	-1.978	.945

Based on estimated marginal means

a. Dependent Variable: Resting heart rate.

b. Adjustment for multiple comparisons: Bonferroni.

3. Environment

Estimates^a

Environment	Mean	Std. Error	df	95% Confidence Interval	
				Lower Bound	Upper Bound
no people	74.119 ^b	7.456	156	59.391	88.848
few people	73.034 ^b	7.456	156	58.306	87.762
lots of people	73.942 ^b	7.457	156	59.211	88.673

a. Dependent Variable: Resting heart rate.

b. Covariates appearing in the model are evaluated at the following values: Age = 30.17, Man_dummyvariable = .2717, NonW_dummyvariable = .2486, Couple_nochild_dummyvariable = .3353, Household_other_dummyvariable = .3873, Baseline stress = 7.55, Baseline hedonic tone = 13.36, Baseline energy = 12.23, Loneliness = 34.40, Trait social connectedness = 92.13, Connectedness_to_nature_average = 3.5628.

Pairwise Comparisons^a

(I) Environment	(J) Environment	Mean Difference (I-J)	Std. Error	df	Sig. ^b	95% Confidence Interval for Difference ^b	
						Lower Bound	Upper Bound
no people	few people	1.085	.898	137.118	.686	-1.090	3.261
	lots of people	.177	.898	136.980	1.000	-1.998	2.353
few people	no people	-1.085	.898	137.118	.686	-3.261	1.090
	lots of people	-.908	.898	137.040	.941	-3.084	1.268
lots of people	no people	-.177	.898	136.980	1.000	-2.353	1.998
	few people	.908	.898	137.040	.941	-1.268	3.084

Based on estimated marginal means

a. Dependent Variable: Resting heart rate.

b. Adjustment for multiple comparisons: Bonferroni.

4. Timepoint * Environment

Estimates^a

Timepoint	Environment	Mean	Std. Error	df	95% Confidence Interval	
					Lower Bound	Upper Bound
Pre environment	no people	74.251 ^b	7.481	156	59.473	89.029
	few people	74.223 ^b	7.481	156	59.446	89.000
	lots of people	73.396 ^b	7.483	156	58.614	88.178
Post environment	no people	73.988 ^b	7.486	156	59.201	88.774
	few people	71.845 ^b	7.486	156	57.058	86.631
	lots of people	74.488 ^b	7.486	156	59.701	89.274

a. Dependent Variable: Resting heart rate.

b. Covariates appearing in the model are evaluated at the following values: Age = 30.17, Man_dummyvariable = .2717, NonW_dummyvariable = .2486, Couple_nochild_dummyvariable = .3353, Household_other_dummyvariable = .3873, Baseline stress = 7.55, Baseline hedonic tone = 13.36, Baseline energy = 12.23, Loneliness = 34.40, Trait social connectedness = 92.13, Connectedness_to_nature_average = 3.5628.

Pairwise Comparisons^a

Environment	(I) Timepoint	(J) Timepoint	Mean Difference (I-J)	Std. Error	df	Sig. ^b	95% Confidence Interval for Difference ^b	
							Lower Bound	Upper Bound
no people	Pre environment	Post environment	.263	1.273	137.142	.836	-2.254	2.780
	Post environment	Pre environment	-.263	1.273	137.142	.836	-2.780	2.254
few people	Pre environment	Post environment	2.378	1.273	137.215	.064	-.139	4.895
	Post environment	Pre environment	-2.378	1.273	137.215	.064	-4.895	.139
lots of people	Pre environment	Post environment	-1.092	1.273	136.916	.393	-3.610	1.427
	Post environment	Pre environment	1.092	1.273	136.916	.393	-1.427	3.610

Based on estimated marginal means

a. Dependent Variable: Resting heart rate.

b. Adjustment for multiple comparisons: Bonferroni.

Heart rate – middle to older adults

Information Criteria^a

-2 Restricted Log Likelihood	765.12051386
Akaike's Information Criterion (AIC)	771.12051386
Hurvich and Tsai's Criterion (AICC)	771.31563582
Bozdogan's Criterion (CAIC)	782.65307512
Schwarz's Bayesian Criterion (BIC)	779.65307512

The information criteria are displayed in smaller-is-better form.

a. Dependent Variable: Resting heart rate.

Fixed Effects

Type III Tests of Fixed Effects^a

Source	Numerator df	Denominator df	F	Sig.
Intercept	1	13.231	.821	.381
Timepoint	1	114.063	2.244	.137
Environment	2	114.063	7.079	.001
Timepoint * Environment	2	114.063	4.233	.017
Age	1	13.116	2.017	.179
Man_dummyvariable	1	13.027	.134	.720
NonW_dummyvariable	1	13.057	1.166	.300
Couple_nochild_dummyvariable	1	13.112	.365	.556
Household_other_dummyvariable	1	13.057	2.133	.168
Baseline_stress	1	13.094	.580	.460
Baseline_hedonic_tone	1	117.995	.833	.363
Baseline_energy	1	13.025	8.044	.014
Loneliness	1	13.041	6.387	.025
Trait_social_connectedness	1	13.019	9.476	.009
Connectedness_to_nature_average	1	13.113	2.544	.135

a. Dependent Variable: Resting heart rate.

2. Timepoint

Estimates^a

Timepoint	Mean	Std. Error	df	95% Confidence Interval	
				Lower Bound	Upper Bound
Pre environment	69.882 ^b	4.988	127	60.011	79.753
Post environment	69.146 ^b	4.988	127	59.275	79.016

a. Dependent Variable: Resting heart rate.

b. Covariates appearing in the model are evaluated at the following values: Age = 46.75, Man_dummyvariable = .2500, NonW_dummyvariable = .1250, Couple_nochild_dummyvariable = .2083, Household_other_dummyvariable = .2917, Baseline stress = 7.58, Baseline hedonic tone = 13.85, Baseline energy = 11.83, Loneliness = 33.92, Trait social connectedness = 92.67, Connectedness_to_nature_average = 3.7500.

Pairwise Comparisons^a

(I) Timepoint	(J) Timepoint	Mean Difference (I-J)	Std. Error	df	Sig. ^b	95% Confidence Interval for Difference ^b	
						Lower Bound	Upper Bound
Pre environment	Post environment	.736	.492	114.063	.137	-.238	1.711
Post environment	Pre environment	-.736	.492	114.063	.137	-1.711	.238

Based on estimated marginal means

a. Dependent Variable: Resting heart rate.

b. Adjustment for multiple comparisons: Bonferroni.

3. Environment

Estimates^a

Environment	Mean	Std. Error	df	95% Confidence Interval	
				Lower Bound	Upper Bound
no people	70.666 ^b	4.994	127	60.783	80.549
few people	69.479 ^b	4.994	127	59.597	79.362
lots of people	68.396 ^b	4.994	127	58.513	78.279

a. Dependent Variable: Resting heart rate.

b. Covariates appearing in the model are evaluated at the following values: Age = 46.75, Man_dummyvariable = .2500, NonW_dummyvariable = .1250, Couple_nochild_dummyvariable = .2083, Household_other_dummyvariable = .2917, Baseline stress = 7.58, Baseline hedonic tone = 13.85, Baseline energy = 11.83, Loneliness = 33.92, Trait social connectedness = 92.67, Connectedness_to_nature_average = 3.7500.

Pairwise Comparisons^a

(I) Environment	(J) Environment	Mean Difference (I-J)	Std. Error	df	Sig. ^c	95% Confidence Interval for Difference ^c	
						Lower Bound	Upper Bound
no people	few people	1.187	.603	114.081	.155	-.279	2.653
	lots of people	2.270 [*]	.603	114.081	<.001	.804	3.737
few people	no people	-1.187	.603	114.081	.155	-2.653	.279
	lots of people	1.083	.600	114.027	.220	-.374	2.540
lots of people	no people	-2.270 [*]	.603	114.081	<.001	-3.737	-.804
	few people	-1.083	.600	114.027	.220	-2.540	.374

Based on estimated marginal means

*. The mean difference is significant at the .05 level.

a. Dependent Variable: Resting heart rate.

c. Adjustment for multiple comparisons: Bonferroni

4. Timepoint * Environment

Estimates^a

Timepoint	Environment	Mean	Std. Error	df	95% Confidence Interval	
					Lower Bound	Upper Bound
Pre environment	no people	72.021 ^b	5.012	127	62.103	81.939
	few people	69.563 ^b	5.012	127	59.645	79.481
	lots of people	68.063 ^b	5.012	127	58.145	77.981
Post environment	no people	69.312 ^b	5.013	127	59.391	79.232
	few people	69.396 ^b	5.012	127	59.478	79.314
	lots of people	68.729 ^b	5.012	127	58.811	78.648

a. Dependent Variable: Resting heart rate.

b. Covariates appearing in the model are evaluated at the following values: Age = 46.75, Man_dummyvariable = .2500, NonW_dummyvariable = .1250, Couple_nochild_dummyvariable = .2083, Household_other_dummyvariable = .2917, Baseline stress = 7.58, Baseline hedonic tone = 13.85, Baseline energy = 11.83, Loneliness = 33.92, Trait social connectedness = 92.67, Connectedness_to_nature_average = 3.7500.

Pairwise Comparisons^a

Environment	(I) Timepoint	(J) Timepoint	Mean Difference (I-J)	Std. Error	df	Sig. ^c	95% Confidence Interval for Difference ^c	
							Lower Bound	Upper Bound
no people	Pre environment	Post environment	2.709 [*]	.859	114.132	.002	1.008	4.411
	Post environment	Pre environment	-2.709 [*]	.859	114.132	.002	-4.411	-1.008
few people	Pre environment	Post environment	.167	.848	114.027	.845	-1.513	1.847
	Post environment	Pre environment	-.167	.848	114.027	.845	-1.847	1.513
lots of people	Pre environment	Post environment	-.667	.848	114.027	.433	-2.347	1.013
	Post environment	Pre environment	.667	.848	114.027	.433	-1.013	2.347

Based on estimated marginal means

*. The mean difference is significant at the .05 level.

a. Dependent Variable: Resting heart rate.

c. Adjustment for multiple comparisons: Bonferroni.

Systolic blood pressure – younger adults (18-24 yrs)

Information Criteria^a

-2 Restricted Log Likelihood	1167.0595935
Akaike's Information Criterion (AIC)	1173.0595935
Hurvich and Tsai's Criterion (AICC)	1173.2174883
Bozdogan's Criterion (CAIC)	1185.2091616
Schwarz's Bayesian Criterion (BIC)	1182.2091616

The information criteria are displayed in smaller-is-better form.

a. Dependent Variable: Resting systolic blood pressure.

Fixed Effects

Type III Tests of Fixed Effects^a

Source	Numerator df	Denominator df	F	Sig.
Intercept	1	17.102	4.600	.047
Timepoint	1	136.596	.737	.392
Environment	2	135.800	2.763	.067
Timepoint * Environment	2	135.800	.134	.874
Age	1	17.217	.166	.689
Man_dummyvariable	1	17.489	7.141	.016
NonW_dummyvariable	1	19.206	1.561	.226
Couple_nochild_dummyvariable	1	19.242	6.160	.022
Household_other_dummyvariable	1	16.321	.511	.485
Baseline_stress	1	17.449	.006	.941
Baseline_hedonic_tone	1	16.298	.185	.673
Baseline_energy	1	16.702	2.233	.154
Loneliness	1	17.021	.020	.888
Trait_social_connectedness	1	16.240	.835	.374
Connectedness_to_nature_average	1	18.260	.287	.599

a. Dependent Variable: Resting systolic blood pressure.

2. Timepoint

Estimates^a

Timepoint	Mean	Std. Error	df	95% Confidence Interval	
				Lower Bound	Upper Bound
Pre environment	123.481 ^b	5.411	156	112.794	134.168
Post environment	122.560 ^b	5.417	156	111.860	133.260

a. Dependent Variable: Resting systolic blood pressure.

b. Covariates appearing in the model are evaluated at the following values: Age = 30.17, Man_dummyvariable = .2717, NonW_dummyvariable = .2486, Couple_nochild_dummyvariable = .3353, Household_other_dummyvariable = .3873, Baseline stress = 7.55, Baseline hedonic tone = 13.36, Baseline energy = 12.23, Loneliness = 34.40, Trait social connectedness = 92.13, Connectedness_to_nature_average = 3.5628.

Pairwise Comparisons^a

(I) Timepoint	(J) Timepoint	Mean Difference (I-J)	Std. Error	df	Sig. ^b	95% Confidence Interval for Difference ^b	
						Lower Bound	Upper Bound
Pre environment	Post environment	.921	1.073	136.596	.392	-1.200	3.042
Post environment	Pre environment	-.921	1.073	136.596	.392	-3.042	1.200

Based on estimated marginal means

a. Dependent Variable: Resting systolic blood pressure.

b. Adjustment for multiple comparisons: Bonferroni.

3. Environment

Estimates^a

Environment	Mean	Std. Error	df	95% Confidence Interval	
				Lower Bound	Upper Bound
no people	124.767 ^b	5.439	156	114.024	135.510
few people	121.900 ^b	5.438	156	111.158	132.642
lots of people	122.395 ^b	5.441	156	111.647	133.143

a. Dependent Variable: Resting systolic blood pressure.

b. Covariates appearing in the model are evaluated at the following values: Age = 30.17, Man_dummyvariable = .2717, NonW_dummyvariable = .2486, Couple_nochild_dummyvariable = .3353, Household_other_dummyvariable = .3873, Baseline stress = 7.55, Baseline hedonic tone = 13.36, Baseline energy = 12.23, Loneliness = 34.40, Trait social connectedness = 92.13, Connectedness_to_nature_average = 3.5628.

Pairwise Comparisons^a

(I) Environment	(J) Environment	Mean Difference (I-J)	Std. Error	df	Sig. ^b	95% Confidence Interval for Difference ^b	
						Lower Bound	Upper Bound
no people	few people	2.867	1.303	136.146	.089	-.292	6.026
	lots of people	2.372	1.305	135.554	.214	-.792	5.535
few people	no people	-2.867	1.303	136.146	.089	-6.026	.292
	lots of people	-.495	1.304	135.702	1.000	-3.657	2.667
lots of people	no people	-2.372	1.305	135.554	.214	-5.535	.792
	few people	.495	1.304	135.702	1.000	-2.667	3.657

Based on estimated marginal means

a. Dependent Variable: Resting systolic blood pressure.

b. Adjustment for multiple comparisons: Bonferroni.

4. Timepoint * Environment

Estimates^a

Timepoint	Environment	Mean	Std. Error	df	95% Confidence Interval	
					Lower Bound	Upper Bound
Pre environment	no people	124.985 ^b	5.511	156	114.100	135.870
	few people	122.216 ^b	5.510	156	111.333	133.099
	lots of people	123.242 ^b	5.516	156	112.346	134.138
Post environment	no people	124.548 ^b	5.523	156	113.639	135.457
	few people	121.584 ^b	5.523	156	110.675	132.493
	lots of people	121.548 ^b	5.523	156	110.639	132.457

a. Dependent Variable: Resting systolic blood pressure.

b. Covariates appearing in the model are evaluated at the following values: Age = 30.17, Man_dummyvariable = .2717, NonW_dummyvariable = .2486, Couple_nochild_dummyvariable = .3353, Household_other_dummyvariable = .3873, Baseline stress = 7.55, Baseline hedonic tone = 13.36, Baseline energy = 12.23, Loneliness = 34.40, Trait social connectedness = 92.13, Connectedness_to_nature_average = 3.5628.

Pairwise Comparisons^a

Environment	(I) Timepoint	(J) Timepoint	Mean Difference (I-J)	Std. Error	df	Sig. ^b	95% Confidence Interval for Difference ^b	
							Lower Bound	Upper Bound
no people	Pre environment	Post environment	.437	1.848	136.416	.813	-3.217	4.091
	Post environment	Pre environment	-.437	1.848	136.416	.813	-4.091	3.217
few people	Pre environment	Post environment	.632	1.847	136.511	.733	-3.020	4.284
	Post environment	Pre environment	-.632	1.847	136.511	.733	-4.284	3.020
lots of people	Pre environment	Post environment	1.694	1.852	135.279	.362	-1.969	5.357
	Post environment	Pre environment	-1.694	1.852	135.279	.362	-5.357	1.969

Based on estimated marginal means

a. Dependent Variable: Resting systolic blood pressure.

b. Adjustment for multiple comparisons: Bonferroni.

Systolic blood pressure – middle to older adults

Information Criteria^a

-2 Restricted Log Likelihood	898.16122435
Akaike's Information Criterion (AIC)	904.16122435
Hurvich and Tsai's Criterion (AICC)	904.35634630
Bozdogan's Criterion (CAIC)	915.69378561
Schwarz's Bayesian Criterion (BIC)	912.69378561

The information criteria are displayed in smaller-is-better form.

a. Dependent Variable: Resting systolic blood pressure.

Fixed Effects

Type III Tests of Fixed Effects^a

Source	Numerator df	Denominator df	F	Sig.
Intercept	1	13.269	3.203	.096
Timepoint	1	114.027	5.753	.018
Environment	2	114.026	4.835	.010
Timepoint * Environment	2	114.026	1.411	.248
Age	1	13.125	.042	.841
Man_dummyvariable	1	12.857	3.054	.104
NonW_dummyvariable	1	12.947	.836	.377
Couple_nochild_dummyvariable	1	13.112	.674	.426
Household_other_dummyvariable	1	12.948	1.547	.236
Baseline_stress	1	13.058	1.032	.328
Baseline_hedonic_tone	1	124.415	.014	.908
Baseline_energy	1	12.852	1.207	.292
Loneliness	1	12.899	.024	.879
Trait_social_connectedness	1	12.834	.000	.986
Connectedness_to_nature_average	1	13.116	3.068	.103

a. Dependent Variable: Resting systolic blood pressure.

2. Timepoint

Estimates^a

Timepoint	Mean	Std. Error	df	95% Confidence Interval	
				Lower Bound	Upper Bound
Pre environment	125.412 ^b	5.438	127	114.651	136.173
Post environment	123.296 ^b	5.438	127	112.536	134.057

a. Dependent Variable: Resting systolic blood pressure.

b. Covariates appearing in the model are evaluated at the following values: Age = 46.75, Man_dummyvariable = .2500, NonW_dummyvariable = .1250, Couple_nochild_dummyvariable = .2083, Household_other_dummyvariable = .2917, Baseline stress = 7.58, Baseline hedonic tone = 13.85, Baseline energy = 11.83, Loneliness = 33.92, Trait social connectedness = 92.67, Connectedness_to_nature_average = 3.7500.

Pairwise Comparisons^a

(I) Timepoint	(J) Timepoint	Mean Difference (I-J)	Std. Error	df	Sig. ^c	95% Confidence Interval for Difference ^c	
						Lower Bound	Upper Bound
Pre environment	Post environment	2.116 [*]	.882	114.027	.018	.368	3.863
Post environment	Pre environment	-2.116 [*]	.882	114.027	.018	-3.863	-.368

Based on estimated marginal means

*. The mean difference is significant at the .05 level.

a. Dependent Variable: Resting systolic blood pressure.

c. Adjustment for multiple comparisons: Bonferroni.

3. Environment

Estimates^a

Environment	Mean	Std. Error	df	95% Confidence Interval	
				Lower Bound	Upper Bound
no people	126.197 ^b	5.456	127	115.400	136.993
few people	122.891 ^b	5.456	127	112.096	133.687
lots of people	123.975 ^b	5.456	127	113.179	134.770

a. Dependent Variable: Resting systolic blood pressure.

b. Covariates appearing in the model are evaluated at the following values: Age = 46.75, Man_dummyvariable = .2500, NonW_dummyvariable = .1250, Couple_nochild_dummyvariable = .2083, Household_other_dummyvariable = .2917, Baseline stress = 7.58, Baseline hedonic tone = 13.85, Baseline energy = 11.83, Loneliness = 33.92, Trait social connectedness = 92.67, Connectedness_to_nature_average = 3.7500.

Pairwise Comparisons^a

(I) Environment	(J) Environment	Mean Difference (I-J)	Std. Error	df	Sig. ^c	95% Confidence Interval for Difference ^c	
						Lower Bound	Upper Bound
no people	few people	3.306 [*]	1.083	114.081	.008	.675	5.936
	lots of people	2.222	1.083	114.081	.127	-.408	4.853
few people	no people	-3.306 [*]	1.083	114.081	.008	-5.936	-.675
	lots of people	-1.083	1.076	113.918	.948	-3.698	1.531
lots of people	no people	-2.222	1.083	114.081	.127	-4.853	.408
	few people	1.083	1.076	113.918	.948	-1.531	3.698

Based on estimated marginal means

*. The mean difference is significant at the .05 level.

a. Dependent Variable: Resting systolic blood pressure.

c. Adjustment for multiple comparisons: Bonferroni.

4. Timepoint * Environment

Estimates^a

Timepoint	Environment	Mean	Std. Error	df	95% Confidence Interval	
					Lower Bound	Upper Bound
Pre environment	no people	127.662 ^b	5.508	127	116.762	138.562
	few people	124.579 ^b	5.508	127	113.679	135.479
	lots of people	123.995 ^b	5.508	127	113.095	134.896
Post environment	no people	124.731 ^b	5.512	127	113.824	135.638
	few people	121.204 ^b	5.508	127	110.304	132.104
	lots of people	123.954 ^b	5.508	127	113.054	134.854

a. Dependent Variable: Resting systolic blood pressure.

b. Covariates appearing in the model are evaluated at the following values: Age = 46.75, Man_dummyvariable = .2500, NonW_dummyvariable = .1250, Couple_nochild_dummyvariable = .2083, Household_other_dummyvariable = .2917, Baseline stress = 7.58, Baseline hedonic tone = 13.85, Baseline energy = 11.83, Loneliness = 33.92, Trait social connectedness = 92.67, Connectedness_to_nature_average = 3.7500.

Pairwise Comparisons^a

Environment	(I) Timepoint	(J) Timepoint	Mean Difference (I-J)	Std. Error	df	Sig. ^c	95% Confidence Interval for Difference ^c	
							Lower Bound	Upper Bound
no people	Pre environment	Post environment	2.931	1.540	114.240	.060	-.121	5.982
	Post environment	Pre environment	-2.931	1.540	114.240	.060	-5.982	.121
few people	Pre environment	Post environment	3.375 [*]	1.522	113.918	.029	.361	6.389
	Post environment	Pre environment	-3.375 [*]	1.522	113.918	.029	-6.389	-.361
lots of people	Pre environment	Post environment	.042	1.522	113.918	.978	-2.973	3.056
	Post environment	Pre environment	-.042	1.522	113.918	.978	-3.056	2.973

Based on estimated marginal means

*. The mean difference is significant at the .05 level.

a. Dependent Variable: Resting systolic blood pressure.

c. Adjustment for multiple comparisons: Bonferroni.

Diastolic blood pressure – younger adults (18-24 yrs)

Information Criteria^a

-2 Restricted Log Likelihood	1104.2388300
Akaike's Information Criterion (AIC)	1110.2388300
Hurvich and Tsai's Criterion (AICC)	1110.3967248
Bozdogan's Criterion (CAIC)	1122.3883981
Schwarz's Bayesian Criterion (BIC)	1119.3883981

The information criteria are displayed in smaller-is-better form.

a. Dependent Variable: Resting diastolic blood pressure.

Fixed Effects

Type III Tests of Fixed Effects ^a				
Source	Numerator df	Denominator df	F	Sig.
Intercept	1	17.644	4.860	.041
Timepoint	1	136.777	3.791	.054
Environment	2	136.183	1.490	.229
Timepoint * Environment	2	136.183	.638	.530
Age	1	17.735	.545	.470
Man_dummyvariable	1	17.983	1.437	.246
NonW_dummyvariable	1	19.388	1.241	.279
Couple_nochild_dummyvariable	1	19.407	2.893	.105
Household_other_dummyvariable	1	16.974	.030	.865
Baseline_stress	1	17.893	1.611	.221
Baseline_hedonic_tone	1	16.956	3.420	.082
Baseline_energy	1	17.275	2.285	.149
Loneliness	1	17.566	.156	.698
Trait_social_connectedness	1	16.907	.445	.514
Connectedness_to_nature_average	1	18.573	.119	.734

a. Dependent Variable: Resting diastolic blood pressure.

2. Timepoint

Estimates^a

Timepoint	Mean	Std. Error	df	95% Confidence Interval	
				Lower Bound	Upper Bound
Pre environment	82.794 ^b	4.729	156	73.453	92.136
Post environment	81.120 ^b	4.734	156	71.769	90.471

a. Dependent Variable: Resting diastolic blood pressure.

b. Covariates appearing in the model are evaluated at the following values: Age = 30.17, Man_dummyvariable = .2717, NonW_dummyvariable = .2486, Couple_nochild_dummyvariable = .3353, Household_other_dummyvariable = .3873, Baseline stress = 7.55, Baseline hedonic tone = 13.36, Baseline energy = 12.23, Loneliness = 34.40, Trait social connectedness = 92.13, Connectedness_to_nature_average = 3.5628.

Pairwise Comparisons^a

(I) Timepoint	(J) Timepoint	Mean Difference (I-J)	Std. Error	df	Sig. ^b	95% Confidence Interval for Difference ^b	
						Lower Bound	Upper Bound
Pre environment	Post environment	1.675	.860	136.777	.054	-.026	3.376
Post environment	Pre environment	-1.675	.860	136.777	.054	-3.376	.026

Based on estimated marginal means

a. Dependent Variable: Resting diastolic blood pressure.

b. Adjustment for multiple comparisons: Bonferroni.

3. Environment

Estimates^a

Environment	Mean	Std. Error	df	95% Confidence Interval	
				Lower Bound	Upper Bound
no people	82.912 ^b	4.750	156	73.529	92.294
few people	81.119 ^b	4.750	156	71.737	90.501
lots of people	81.840 ^b	4.752	156	72.454	91.227

a. Dependent Variable: Resting diastolic blood pressure.

b. Covariates appearing in the model are evaluated at the following values: Age = 30.17, Man_dummyvariable = .2717, NonW_dummyvariable = .2486, Couple_nochild_dummyvariable = .3353, Household_other_dummyvariable = .3873, Baseline stress = 7.55, Baseline hedonic tone = 13.36, Baseline energy = 12.23, Loneliness = 34.40, Trait social connectedness = 92.13, Connectedness_to_nature_average = 3.5628.

Pairwise Comparisons^a

(I) Environment	(J) Environment	Mean Difference (I-J)	Std. Error	df	Sig. ^b	95% Confidence Interval for Difference ^b	
						Lower Bound	Upper Bound
no people	few people	1.792	1.045	136.460	.266	-.740	4.325
	lots of people	1.071	1.046	135.972	.923	-1.464	3.606
few people	no people	-1.792	1.045	136.460	.266	-4.325	.740
	lots of people	-.721	1.046	136.121	1.000	-3.256	1.813
lots of people	no people	-1.071	1.046	135.972	.923	-3.606	1.464
	few people	.721	1.046	136.121	1.000	-1.813	3.256

Based on estimated marginal means

a. Dependent Variable: Resting diastolic blood pressure.

b. Adjustment for multiple comparisons: Bonferroni.

4. Timepoint * Environment

Estimates ^a						
Timepoint	Environment	Mean	Std. Error	df	95% Confidence Interval	
					Lower Bound	Upper Bound
Pre environment	no people	84.311 ^b	4.803	156	74.823	93.798
	few people	82.011 ^b	4.802	156	72.526	91.497
	lots of people	82.061 ^b	4.807	156	72.566	91.557
Post environment	no people	81.512 ^b	4.812	156	72.008	91.017
	few people	80.227 ^b	4.812	156	70.722	89.732
	lots of people	81.620 ^b	4.812	156	72.115	91.124

a. Dependent Variable: Resting diastolic blood pressure.

b. Covariates appearing in the model are evaluated at the following values: Age = 30.17, Man_dummyvariable = .2717, NonW_dummyvariable = .2486, Couple_nochild_dummyvariable = .3353, Household_other_dummyvariable = .3873, Baseline stress = 7.55, Baseline hedonic tone = 13.36, Baseline energy = 12.23, Loneliness = 34.40, Trait social connectedness = 92.13, Connectedness_to_nature_average = 3.5628.

Pairwise Comparisons ^a								
Environment	(I) Timepoint	(J) Timepoint	Mean Difference (I-J)	Std. Error	df	Sig. ^b	95% Confidence Interval for Difference ^b	
							Lower Bound	Upper Bound
no people	Pre environment	Post environment	2.798	1.482	136.640	.061	-.132	5.728
	Post environment	Pre environment	-2.798	1.482	136.640	.061	-5.728	.132
few people	Pre environment	Post environment	1.784	1.481	136.770	.230	-1.144	4.713
	Post environment	Pre environment	-1.784	1.481	136.770	.230	-4.713	1.144
lots of people	Pre environment	Post environment	.442	1.484	135.742	.766	-2.494	3.377
	Post environment	Pre environment	-.442	1.484	135.742	.766	-3.377	2.494

Based on estimated marginal means

a. Dependent Variable: Resting diastolic blood pressure.

b. Adjustment for multiple comparisons: Bonferroni.

Diastolic blood pressure - middle to older adults

Information Criteria ^a	
-2 Restricted Log Likelihood	821.15944115
Akaike's Information Criterion (AIC)	827.15944115
Hurvich and Tsai's Criterion (AICC)	827.35456310
Bozdogan's Criterion (CAIC)	838.69200241
Schwarz's Bayesian Criterion (BIC)	835.69200241

The information criteria are displayed in smaller-is-better form.

a. Dependent Variable: Resting diastolic blood pressure.

Fixed Effects

Type III Tests of Fixed Effects^a

Source	Numerator df	Denominator df	F	Sig.
Intercept	1	13.219	3.321	.091
Timepoint	1	113.964	5.210	.024
Environment	2	113.963	6.257	.003
Timepoint * Environment	2	113.963	5.407	.006
Age	1	13.070	.201	.661
Man_dummyvariable	1	12.768	.913	.357
NonW_dummyvariable	1	12.869	.445	.516
Couple_nochild_dummyvariable	1	13.055	1.576	.231
Household_other_dummyvariable	1	12.870	1.737	.210
Baseline_stress	1	12.995	1.556	.234
Baseline_hedonic_tone	1	125.303	3.714	.056
Baseline_energy	1	12.763	.603	.452
Loneliness	1	12.815	.207	.657
Trait_social_connectedness	1	12.742	.012	.916
Connectedness_to_nature_average	1	13.060	1.905	.191

a. Dependent Variable: Resting diastolic blood pressure.

2. Timepoint

Estimates^a

Timepoint	Mean	Std. Error	df	95% Confidence Interval	
				Lower Bound	Upper Bound
Pre environment	86.221 ^b	3.832	127	78.638	93.804
Post environment	84.723 ^b	3.832	127	77.140	92.307

a. Dependent Variable: Resting diastolic blood pressure.

b. Covariates appearing in the model are evaluated at the following values: Age = 46.75, Man_dummyvariable = .2500, NonW_dummyvariable = .1250, Couple_nochild_dummyvariable = .2083, Household_other_dummyvariable = .2917, Baseline stress = 7.58, Baseline hedonic tone = 13.85, Baseline energy = 11.83, Loneliness = 33.92, Trait social connectedness = 92.67, Connectedness_to_nature_average = 3.7500.

Pairwise Comparisons^a

(I) Timepoint	(J) Timepoint	Mean Difference (I-J)	Std. Error	df	Sig. ^c	95% Confidence Interval for Difference ^c	
						Lower Bound	Upper Bound
Pre environment	Post environment	1.498 [*]	.656	113.964	.024	.198	2.798
Post environment	Pre environment	-1.498 [*]	.656	113.964	.024	-2.798	-.198

Based on estimated marginal means

*. The mean difference is significant at the .05 level.

a. Dependent Variable: Resting diastolic blood pressure.

c. Adjustment for multiple comparisons: Bonferroni.

3. Environment

Estimates^a

Environment	Mean	Std. Error	df	95% Confidence Interval	
				Lower Bound	Upper Bound
no people	87.009 ^b	3.847	127	79.398	94.621
few people	84.193 ^b	3.846	127	76.582	91.804
lots of people	85.214 ^b	3.846	127	77.603	92.825

a. Dependent Variable: Resting diastolic blood pressure.

b. Covariates appearing in the model are evaluated at the following values: Age = 46.75, Man_dummyvariable = .2500, NonW_dummyvariable = .1250, Couple_nochild_dummyvariable = .2083, Household_other_dummyvariable = .2917, Baseline stress = 7.58, Baseline hedonic tone = 13.85, Baseline energy = 11.83, Loneliness = 33.92, Trait social connectedness = 92.67, Connectedness_to_nature_average = 3.7500.

Pairwise Comparisons^a

(I) Environment	(J) Environment	Mean Difference (I-J)	Std. Error	df	Sig. ^c	95% Confidence Interval for Difference ^c	
						Lower Bound	Upper Bound
no people	few people	2.816 [*]	.805	114.025	.002	.859	4.773
	lots of people	1.795	.805	114.025	.083	-.161	3.752
few people	no people	-2.816 [*]	.805	114.025	.002	-4.773	-.859
	lots of people	-1.021	.800	113.839	.614	-2.966	.924
lots of people	no people	-1.795	.805	114.025	.083	-3.752	.161
	few people	1.021	.800	113.839	.614	-.924	2.966

Based on estimated marginal means

*. The mean difference is significant at the .05 level.

a. Dependent Variable: Resting diastolic blood pressure.

c. Adjustment for multiple comparisons: Bonferroni.

4. Timepoint * Environment

Estimates^a

Timepoint	Environment	Mean	Std. Error	df	95% Confidence Interval	
					Lower Bound	Upper Bound
Pre environment	no people	88.610 ^b	3.888	127	80.917	96.303
	few people	85.610 ^b	3.888	127	77.917	93.303
	lots of people	84.443 ^b	3.888	127	76.750	92.136
Post environment	no people	85.409 ^b	3.890	127	77.710	93.107
	few people	82.777 ^b	3.888	127	75.084	90.470
	lots of people	85.985 ^b	3.888	127	78.292	93.678

a. Dependent Variable: Resting diastolic blood pressure.

b. Covariates appearing in the model are evaluated at the following values: Age = 46.75, Man_dummyvariable = .2500, NonW_dummyvariable = .1250, Couple_nochild_dummyvariable = .2083, Household_other_dummyvariable = .2917, Baseline stress = 7.58, Baseline hedonic tone = 13.85, Baseline energy = 11.83, Loneliness = 33.92, Trait social connectedness = 92.67, Connectedness_to_nature_average = 3.7500.

Pairwise Comparisons^a

Environment	(I) Timepoint	(J) Timepoint	Mean Difference (I-J)	Std. Error	df	Sig. ^c	95% Confidence Interval for Difference ^c	
							Lower Bound	Upper Bound
no people	Pre environment	Post environment	3.201 [*]	1.146	114.206	.006	.932	5.471
	Post environment	Pre environment	-3.201 [*]	1.146	114.206	.006	-5.471	-.932
few people	Pre environment	Post environment	2.833 [*]	1.132	113.839	.014	.591	5.076
	Post environment	Pre environment	-2.833 [*]	1.132	113.839	.014	-5.076	-.591
lots of people	Pre environment	Post environment	-1.542	1.132	113.839	.176	-3.784	.701
	Post environment	Pre environment	1.542	1.132	113.839	.176	-.701	3.784

Based on estimated marginal means

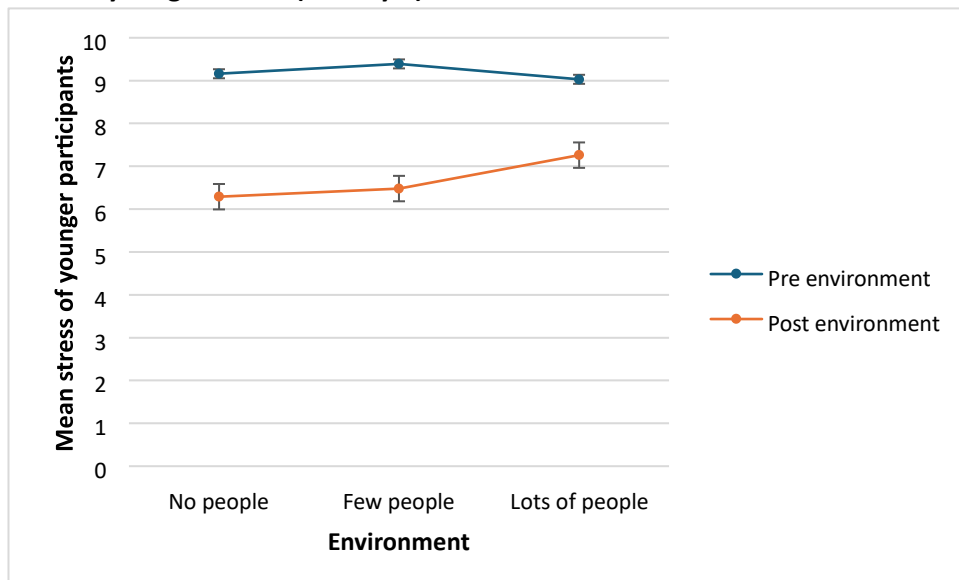
*. The mean difference is significant at the .05 level.

a. Dependent Variable: Resting diastolic blood pressure.

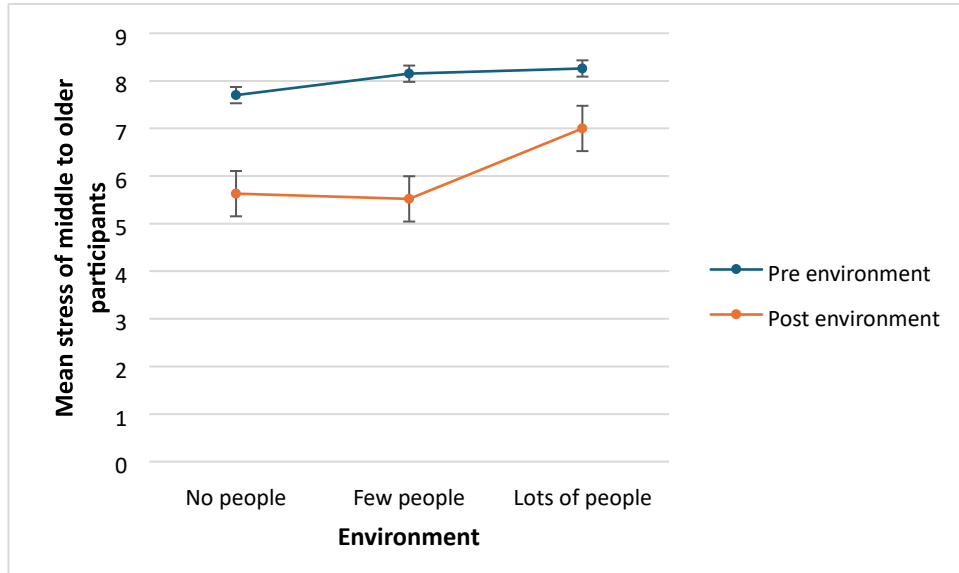
c. Adjustment for multiple comparisons: Bonferroni.

Interaction plots

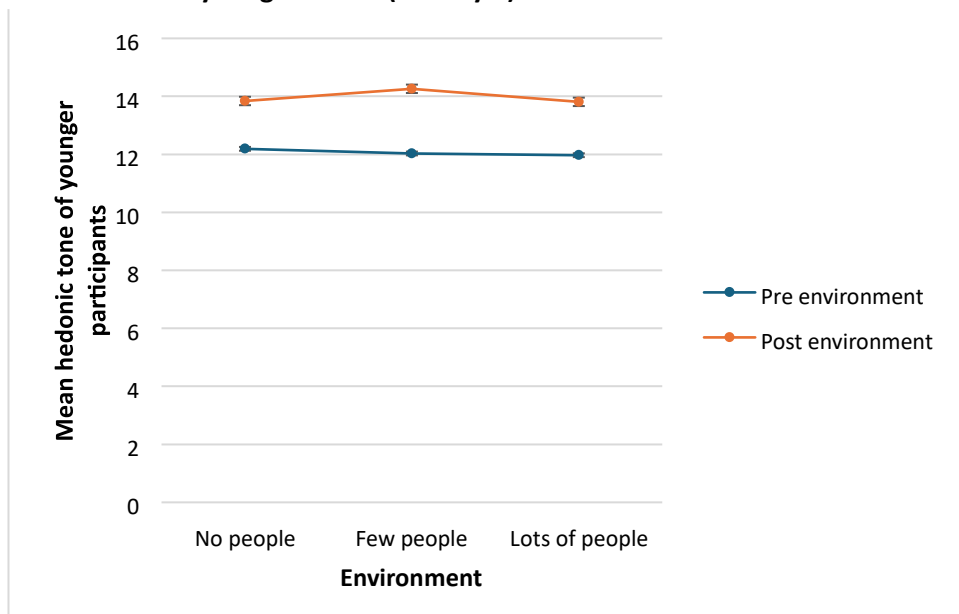
Stress – younger adults (18-24 yrs)



Stress - middle to older adults

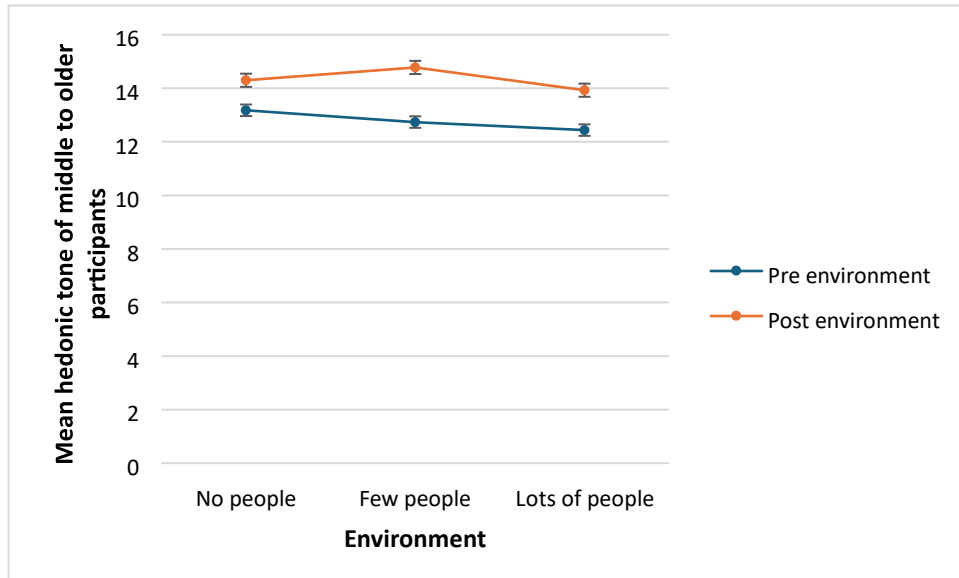


Hedonic tone – younger adults (18-24 yrs)

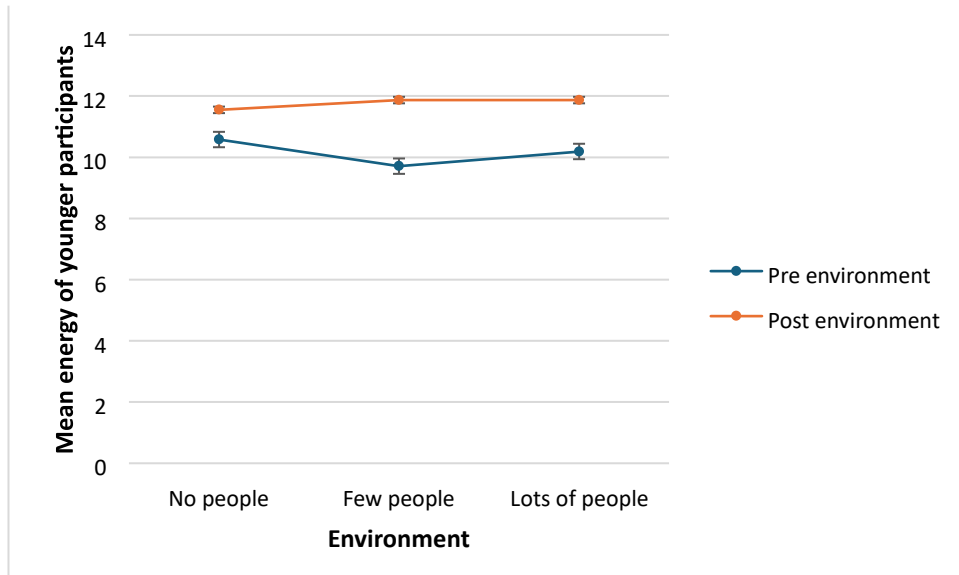


I

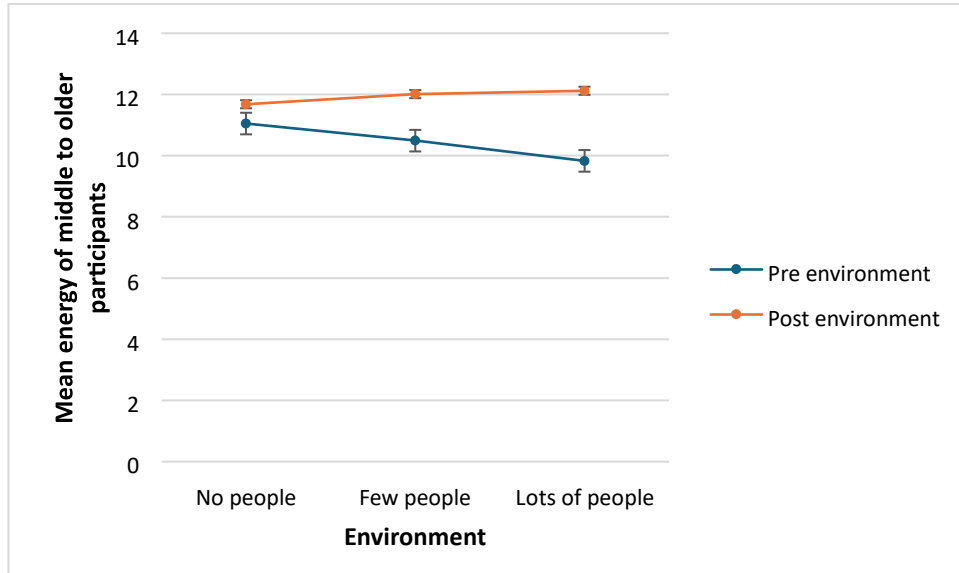
Hedonic tone – middle to older adults



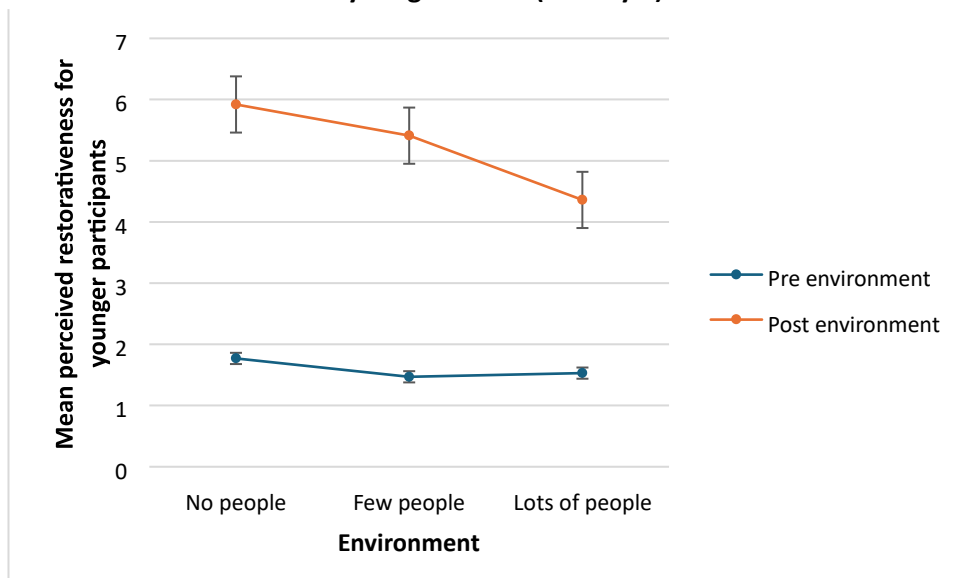
Energy – younger adults (18-24 yrs)



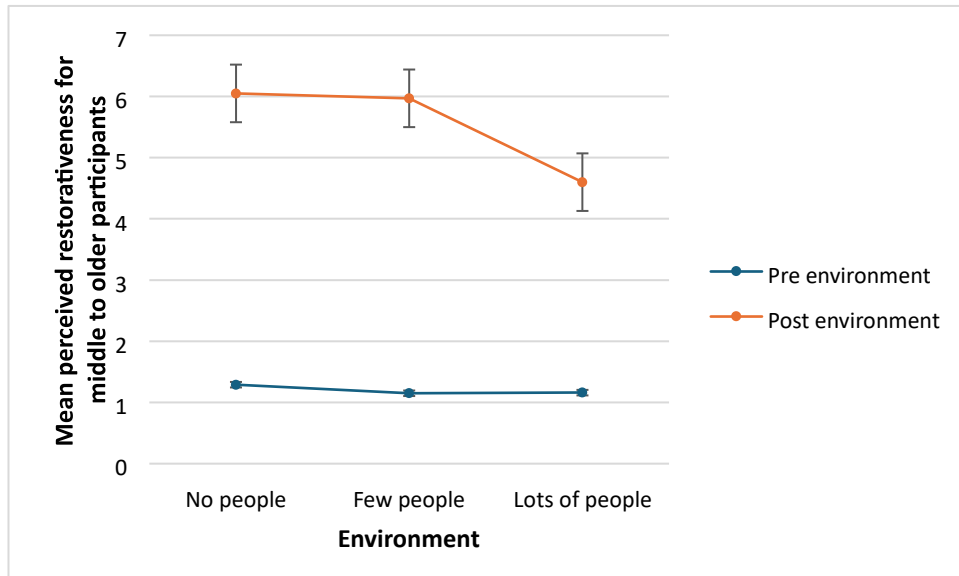
Energy – middle to older adults



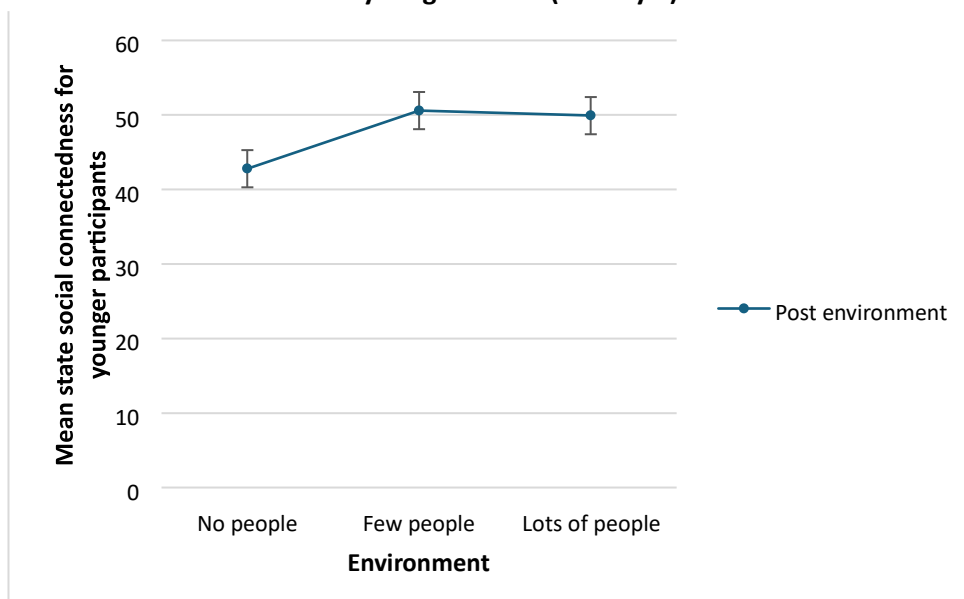
Perceived restorativeness – younger adults (18-24 yrs)



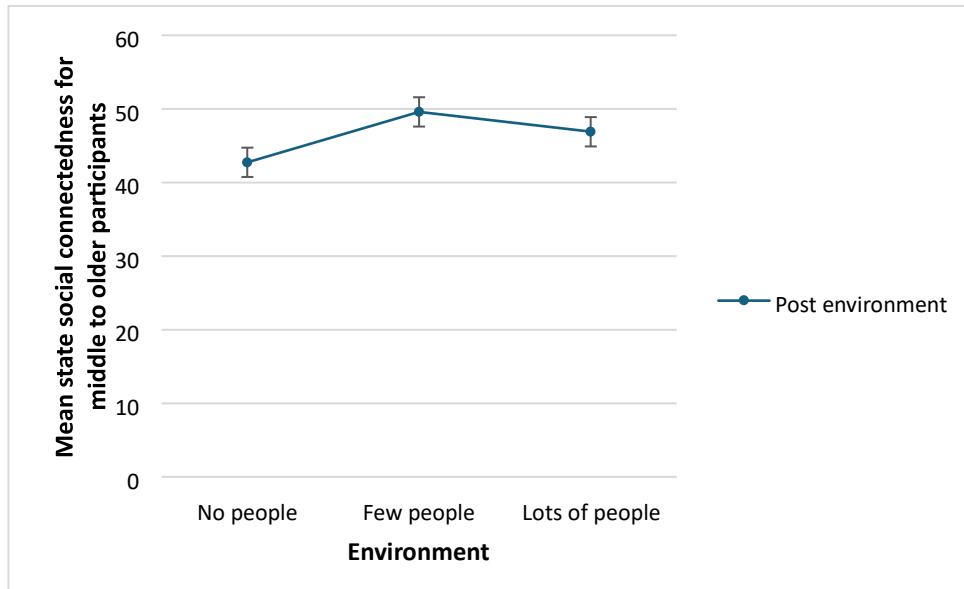
Perceived restorativeness – middle to older adults



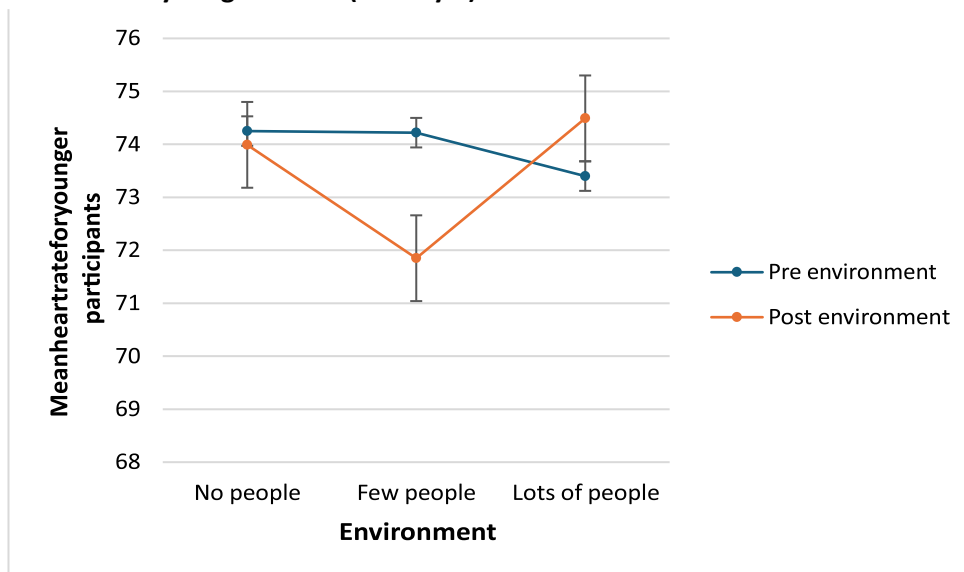
State social connectedness – younger adults (18-24 yrs)



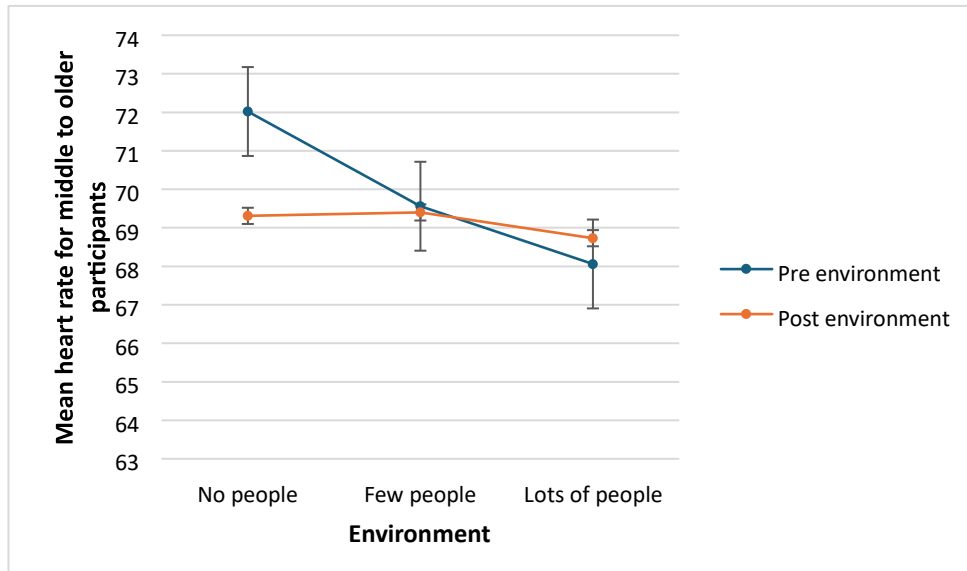
State social connectedness – middle to older adults



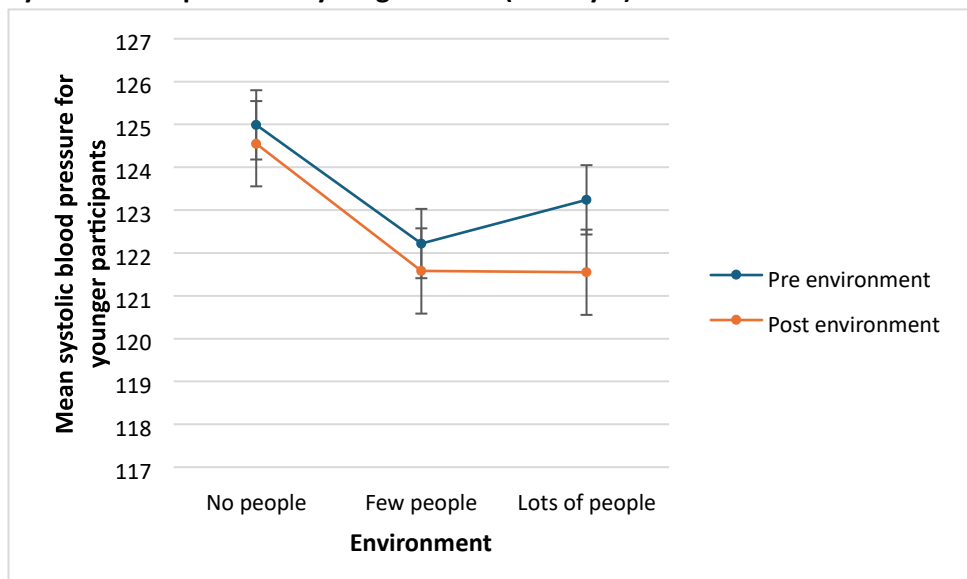
Heart rate – younger adults (18-24 yrs)



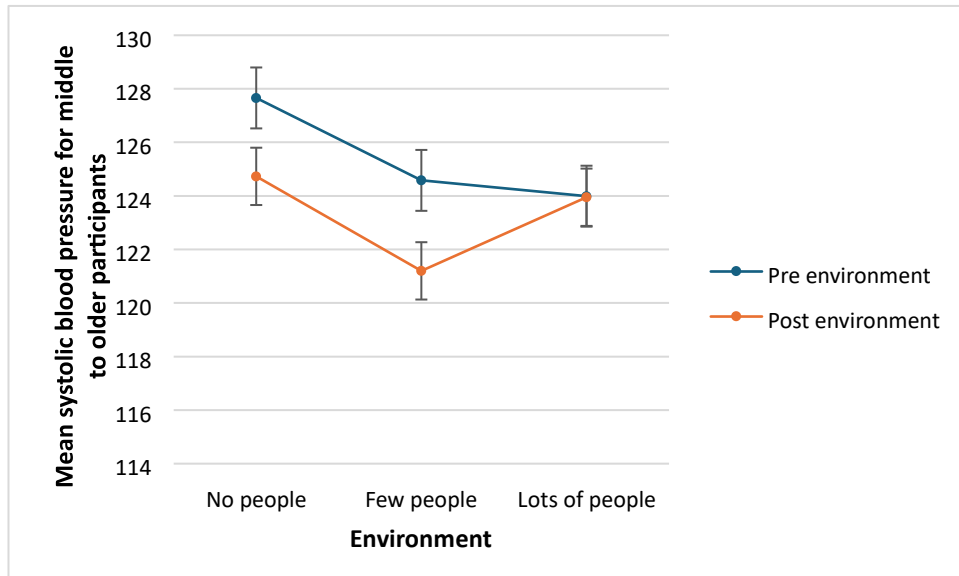
Heart rate – middle to older adults



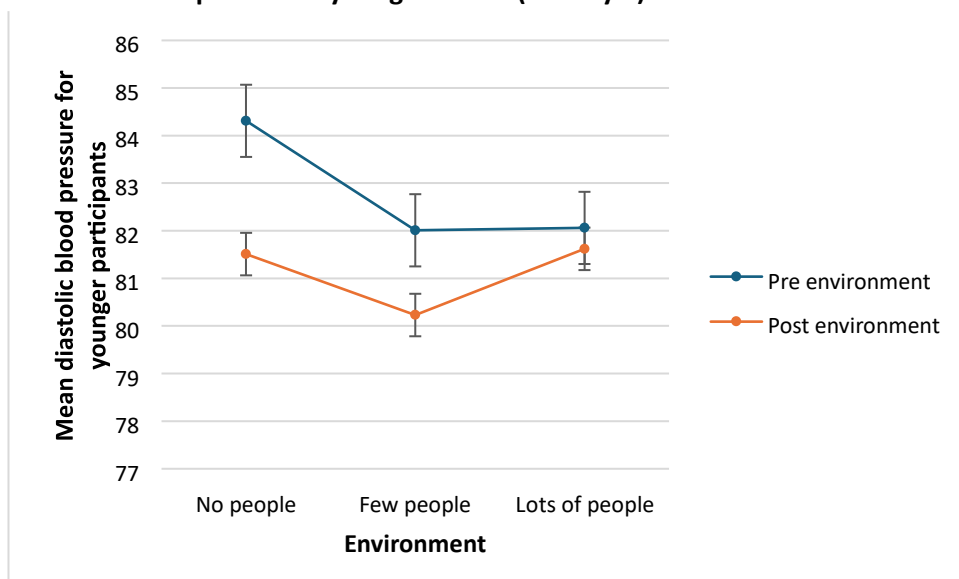
Systolic blood pressure – younger adults (18-24 yrs)



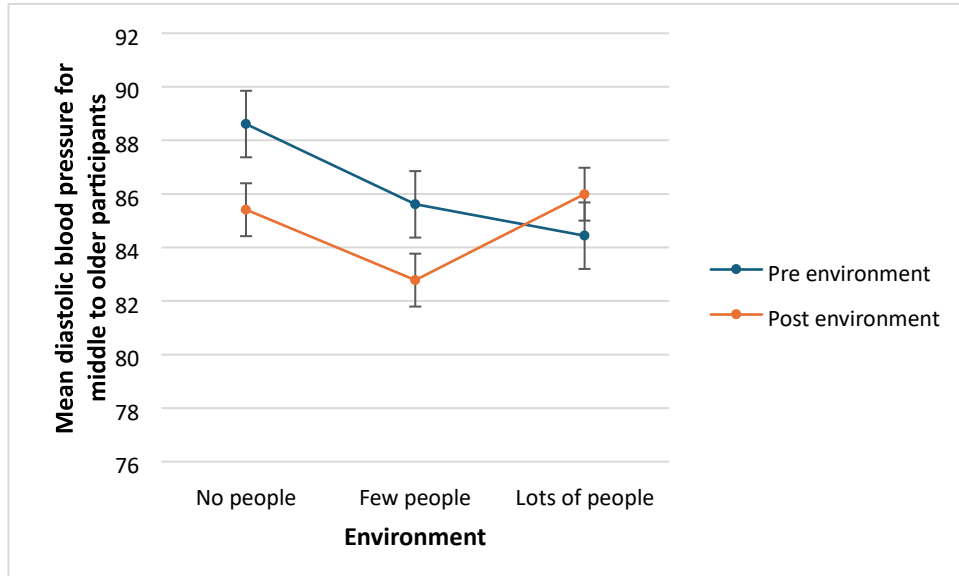
Systolic blood pressure = middle to older adults



Diastolic blood pressure – younger adults (18-24 yrs)



Diastolic blood pressure – middle to older adults



Appendix 28. Chapter 6 additional analysis – PRS individual components

An exploratory analysis of the mean scores for each component of the PRS indicates that all components were scored higher for the environment with no people, except for fascination where no and a few people had a similar rating (see Table 6.13). Across all components, mean scores were lowest following exposure to the busiest environment (environment 3 - lots of people).

PRS component	No people	Few people	Lots of people
Being away	7.29	7.18	5.50
Fascination	5.23	5.67	4.48
Coherence	4.89	4.28	3.50
Scope	5.31	4.79	3.64
Compatibility	7.17	6.39	5.16

Table 6.13. PRS components following exposure to different environments (Mean).

LMM output – Being away

Information Criteria^a

-2 Restricted Log Likelihood	1525.9054516
Akaike's Information Criterion (AIC)	1531.9054516
Hurvich and Tsai's Criterion (AICC)	1531.9788461
Bozdogan's Criterion (CAIC)	1546.3118067
Schwarz's Bayesian Criterion (BIC)	1543.3118067

The information criteria are displayed in smaller-is-better form.

a. Dependent Variable:
PRS_Being_away.

Fixed Effects

Type III Tests of Fixed Effects^a

Source	Numerator df	Denominator df	F	Sig.
Intercept	1	63.907	1.403	.241
Timepoint	1	285.305	672.385	<.001
Environment	2	285.305	8.415	<.001
Timepoint * Environment	2	285.305	6.298	.002
Age	1	48.043	.253	.617
Man_dummyvariable	1	46.551	.071	.791
NonW_dummyvariable	1	47.207	.588	.447
Couple_nochild_dummyvariable	1	46.658	.189	.666
Household_other_dummyvariable	1	46.619	.236	.629
Baseline_stress	1	47.667	.088	.767
Baseline_hedonic_tone	1	80.224	.588	.445
Baseline_energy	1	48.636	.469	.496
Loneliness	1	47.964	.373	.544
Trait_social_connectedness	1	46.686	.016	.900
Connectedness_to_nature_average	1	46.456	1.273	.265

a. Dependent Variable: PRS_Being_away.

2. Timepoint

Estimates^a

Timepoint	Mean	Std. Error	df	95% Confidence Interval	
				Lower Bound	Upper Bound
Pre environment	1.100 ^b	1.260	331	-1.378	3.578
Post environment	6.659 ^b	1.260	331	4.180	9.137

a. Dependent Variable: PRS_Being_away.

b. Covariates appearing in the model are evaluated at the following values: Age = 38.34, Man_dummyvariable = .3103, NonW_dummyvariable = .1897, Couple_nochild_dummyvariable = .2931, Household_other_dummyvariable = .3621, Baseline stress = 7.48, Baseline hedonic tone = 13.70, Baseline energy = 12.12, Loneliness = 34.28, Trait social connectedness = 92.09, Connectedness_to_nature_average = 3.6404.

Pairwise Comparisons^a

(I) Timepoint	(J) Timepoint	Mean Difference (I-J)	Std. Error	df	Sig. ^c	95% Confidence Interval for Difference ^c	
						Lower Bound	Upper Bound
Pre environment	Post environment	-5.558 [*]	.214	285.305	<.001	-5.980	-5.136
Post environment	Pre environment	5.558 [*]	.214	285.305	<.001	5.136	5.980

Based on estimated marginal means

*. The mean difference is significant at the .05 level.

a. Dependent Variable: PRS_Being_away.

c. Adjustment for multiple comparisons: Bonferroni.

3. Environment

Estimates^a

Environment	Mean	Std. Error	df	95% Confidence Interval	
				Lower Bound	Upper Bound
no people	4.245 ^b	1.264	331	1.758	6.732
few people	4.132 ^b	1.264	331	1.645	6.619
lots of people	3.261 ^b	1.264	331	.774	5.748

a. Dependent Variable: PRS_Being_away.

b. Covariates appearing in the model are evaluated at the following values: Age = 38.34, Man_dummyvariable = .3103, NonW_dummyvariable = .1897, Couple_nochild_dummyvariable = .2931, Household_other_dummyvariable = .3621, Baseline stress = 7.48, Baseline hedonic tone = 13.70, Baseline energy = 12.12, Loneliness = 34.28, Trait social connectedness = 92.09, Connectedness_to_nature_average = 3.6404.

Pairwise Comparisons^a

(I) Environment	(J) Environment	Mean Difference (I-J)	Std. Error	df	Sig. ^c	95% Confidence Interval for Difference ^c	
						Lower Bound	Upper Bound
no people	few people	.113	.263	285.489	1.000	-.519	.746
	lots of people	.984 [*]	.263	285.489	<.001	.352	1.616
few people	no people	-.113	.263	285.489	1.000	-.746	.519
	lots of people	.871 [*]	.262	284.937	.003	.239	1.503
lots of people	no people	-.984 [*]	.263	285.489	<.001	-1.616	-.352
	few people	-.871 [*]	.262	284.937	.003	-1.503	-.239

Based on estimated marginal means

*. The mean difference is significant at the .05 level.

a. Dependent Variable: PRS_Being_away.

c. Adjustment for multiple comparisons: Bonferroni.

4. Timepoint * Environment

Estimates^a

Timepoint	Environment	Mean	Std. Error	df	95% Confidence Interval	
					Lower Bound	Upper Bound
Pre environment	no people	1.192 ^b	1.278	331	-1.322	3.706
	few people	1.089 ^b	1.278	331	-1.425	3.602
	lots of people	1.020 ^b	1.278	331	-1.494	3.533
Post environment	no people	7.298 ^b	1.278	331	4.784	9.812
	few people	7.175 ^b	1.278	331	4.661	9.689
	lots of people	5.502 ^b	1.278	331	2.989	8.016

a. Dependent Variable: PRS_Being_away.

b. Covariates appearing in the model are evaluated at the following values: Age = 38.34, Man_dummyvariable = .3103, NonW_dummyvariable = .1897, Couple_nochild_dummyvariable = .2931, Household_other_dummyvariable = .3621, Baseline stress = 7.48, Baseline hedonic tone = 13.70, Baseline energy = 12.12, Loneliness = 34.28, Trait social connectedness = 92.09, Connectedness_to_nature_average = 3.6404.

Pairwise Comparisons^a

Environment	(I) Timepoint	(J) Timepoint	Mean Difference (I-J)	Std. Error	df	Sig. ^c	95% Confidence Interval for Difference ^c	
							Lower Bound	Upper Bound
no people	Pre environment	Post environment	-6.106 [*]	.372	286.039	<.001	-6.838	-5.375
	Post environment	Pre environment	6.106 [*]	.372	286.039	<.001	5.375	6.838
few people	Pre environment	Post environment	-6.086 [*]	.371	284.937	<.001	-6.817	-5.356
	Post environment	Pre environment	6.086 [*]	.371	284.937	<.001	5.356	6.817
lots of people	Pre environment	Post environment	-4.483 [*]	.371	284.937	<.001	-5.213	-3.752
	Post environment	Pre environment	4.483 [*]	.371	284.937	<.001	3.752	5.213

Based on estimated marginal means

*. The mean difference is significant at the .05 level.

a. Dependent Variable: PRS_Being_away.

c. Adjustment for multiple comparisons: Bonferroni.

LMM output – Fascination

Information Criteria^a

-2 Restricted Log Likelihood	1442.1979208
Akaike's Information Criterion (AIC)	1448.1979208
Hurvich and Tsai's Criterion (AICC)	1448.2713153
Bozdogan's Criterion (CAIC)	1462.6042759
Schwarz's Bayesian Criterion (BIC)	1459.6042759

The information criteria are displayed in smaller-is-better form.

a. Dependent Variable:
PRS_Fascination.

Fixed Effects

Type III Tests of Fixed Effects^a

Source	Numerator df	Denominator df	F	Sig.
Intercept	1	62.368	1.972	.165
Timepoint	1	285.289	570.391	<.001
Environment	2	285.288	3.012	.051
Timepoint * Environment	2	285.288	4.687	.010
Age	1	48.666	.945	.336
Man_dummyvariable	1	46.768	2.231	.142
NonW_dummyvariable	1	47.596	1.364	.249
Couple_nochild_dummyvariable	1	46.903	.423	.519
Household_other_dummyvariable	1	46.854	.174	.678
Baseline_stress	1	48.183	.077	.782
Baseline_hedonic_tone	1	108.429	.190	.664
Baseline_energy	1	49.437	.945	.336
Loneliness	1	48.564	.000	.990
Trait_social_connectedness	1	46.938	.227	.636
Connectedness_to_nature_average	1	46.650	.673	.416

a. Dependent Variable: PRS_Fascination.

2. Timepoint

Estimates^a

Timepoint	Mean	Std. Error	df	95% Confidence Interval	
				Lower Bound	Upper Bound
Pre environment	.789 ^b	1.160	331	-1.493	3.070
Post environment	5.131 ^b	1.160	331	2.849	7.412

a. Dependent Variable: PRS_Fascination.

b. Covariates appearing in the model are evaluated at the following values: Age = 38.34, Man_dummyvariable = .3103, NonW_dummyvariable = .1897, Couple_nochild_dummyvariable = .2931, Household_other_dummyvariable = .3621, Baseline stress = 7.48, Baseline hedonic tone = 13.70, Baseline energy = 12.12, Loneliness = 34.28, Trait social connectedness = 92.09, Connectedness_to_nature_average = 3.6404.

Pairwise Comparisons^a

		Mean Difference (I-J)	Std. Error	df	Sig. ^c	95% Confidence Interval for Difference ^c	
(I) Timepoint	(J) Timepoint					Lower Bound	Upper Bound
Pre environment	Post environment	-4.342 [*]	.182	285.289	<.001	-4.700	-3.984
Post environment	Pre environment	4.342 [*]	.182	285.289	<.001	3.984	4.700

Based on estimated marginal means

*. The mean difference is significant at the .05 level.

a. Dependent Variable: PRS_Fascination.

c. Adjustment for multiple comparisons: Bonferroni.

3. Environment

Estimates^a

Environment	Mean	Std. Error	df	95% Confidence Interval	
				Lower Bound	Upper Bound
no people	3.075 ^b	1.163	331	.786	5.363
few people	3.157 ^b	1.163	331	.868	5.445
lots of people	2.648 ^b	1.163	331	.359	4.936

a. Dependent Variable: PRS_Fascination.

b. Covariates appearing in the model are evaluated at the following values: Age = 38.34, Man_dummyvariable = .3103, NonW_dummyvariable = .1897, Couple_nochild_dummyvariable = .2931, Household_other_dummyvariable = .3621, Baseline stress = 7.48, Baseline hedonic tone = 13.70, Baseline energy = 12.12, Loneliness = 34.28, Trait social connectedness = 92.09, Connectedness_to_nature_average = 3.6404.

Pairwise Comparisons^a

(I) Environment	(J) Environment	Mean Difference (I-J)	Std. Error	df	Sig. ^b	95% Confidence Interval for Difference ^b	
						Lower Bound	Upper Bound
no people	few people	-.082	.223	285.517	1.000	-.618	.455
	lots of people	.427	.223	285.517	.169	-.110	.963
few people	no people	.082	.223	285.517	1.000	-.455	.618
	lots of people	.509	.223	284.831	.069	-.027	1.044
lots of people	no people	-.427	.223	285.517	.169	-.963	.110
	few people	-.509	.223	284.831	.069	-1.044	.027

Based on estimated marginal means

a. Dependent Variable: PRS_Fascination.

b. Adjustment for multiple comparisons: Bonferroni.

4. Timepoint * Environment

Estimates^a

Timepoint	Environment	Mean	Std. Error	df	95% Confidence Interval	
					Lower Bound	Upper Bound
Pre environment	no people	.915 ^b	1.174	331	-1.394	3.225
	few people	.639 ^b	1.174	331	-1.670	2.949
	lots of people	.812 ^b	1.174	331	-1.498	3.121
Post environment	no people	5.234 ^b	1.174	331	2.925	7.544
	few people	5.674 ^b	1.174	331	3.364	7.983
	lots of people	4.484 ^b	1.174	331	2.175	6.794

a. Dependent Variable: PRS_Fascination.

b. Covariates appearing in the model are evaluated at the following values: Age = 38.34, Man_dummyvariable = .3103, NonW_dummyvariable = .1897, Couple_nochild_dummyvariable = .2931, Household_other_dummyvariable = .3621, Baseline stress = 7.48, Baseline hedonic tone = 13.70, Baseline energy = 12.12, Loneliness = 34.28, Trait social connectedness = 92.09, Connectedness_to_nature_average = 3.6404.

Pairwise Comparisons^a

Environment	(I) Timepoint	(J) Timepoint	Mean Difference (I-J)	Std. Error	df	Sig. ^c	95% Confidence Interval for Difference ^c	
							Lower Bound	Upper Bound
no people	Pre environment	Post environment	-4.319 [*]	.315	286.199	<.001	-4.940	-3.699
	Post environment	Pre environment	4.319 [*]	.315	286.199	<.001	3.699	4.940
few people	Pre environment	Post environment	-5.034 [*]	.315	284.831	<.001	-5.654	-4.415
	Post environment	Pre environment	5.034 [*]	.315	284.831	<.001	4.415	5.654
lots of people	Pre environment	Post environment	-3.672 [*]	.315	284.831	<.001	-4.292	-3.053
	Post environment	Pre environment	3.672 [*]	.315	284.831	<.001	3.053	4.292

Based on estimated marginal means

*. The mean difference is significant at the .05 level.

a. Dependent Variable: PRS_Fascination.

c. Adjustment for multiple comparisons: Bonferroni.

LMM output – Coherence

Information Criteria^a

-2 Restricted Log Likelihood	1637.4186838
Akaike's Information Criterion (AIC)	1643.4186838
Hurvich and Tsai's Criterion (AICC)	1643.4920783
Bozdogan's Criterion (CAIC)	1657.8250389
Schwarz's Bayesian Criterion (BIC)	1654.8250389

The information criteria are displayed in smaller-is-better form.

a. Dependent Variable: PRS_Coherence.

Fixed Effects

Type III Tests of Fixed Effects^a

Source	Numerator df	Denominator df	F	Sig.
Intercept	1	61.839	.050	.824
Timepoint	1	285.059	35.930	<.001
Environment	2	285.058	3.360	.036
Timepoint * Environment	2	285.058	2.397	.093
Age	1	48.626	.076	.784
Man_dummyvariable	1	46.638	.706	.405
NonW_dummyvariable	1	47.502	1.461	.233
Couple_nochild_dummyvariable	1	46.778	1.685	.201
Household_other_dummyvariable	1	46.727	.489	.488
Baseline_stress	1	48.118	.023	.881
Baseline_hedonic_tone	1	121.727	.078	.780
Baseline_energy	1	49.440	.390	.535
Loneliness	1	48.519	.553	.461
Trait_social_connectedness	1	46.815	.011	.917
Connectedness_to_nature_average	1	46.514	.374	.544

a. Dependent Variable: PRS_Coherence.

2. Timepoint

Estimates^a

Timepoint	Mean	Std. Error	df	95% Confidence Interval	
				Lower Bound	Upper Bound
Pre environment	2.775 ^b	1.592	331	-.356	5.905
Post environment	4.220 ^b	1.592	331	1.089	7.350

a. Dependent Variable: PRS_Coherence.

b. Covariates appearing in the model are evaluated at the following values: Age = 38.34, Man_dummyvariable = .3103, NonW_dummyvariable = .1897, Couple_nochild_dummyvariable = .2931, Household_other_dummyvariable = .3621, Baseline stress = 7.48, Baseline hedonic tone = 13.70, Baseline energy = 12.12, Loneliness = 34.28, Trait social connectedness = 92.09, Connectedness_to_nature_average = 3.6404.

Pairwise Comparisons^a

(I) Timepoint	(J) Timepoint	Mean Difference (I-J)	Std. Error	df	Sig. ^c	95% Confidence Interval for Difference ^c	
Pre environment	Post environment	-1.445 ^a	.241	285.059	<.001	-1.920	-.971
Post environment	Pre environment	1.445 ^a	.241	285.059	<.001	.971	1.920

Based on estimated marginal means

*. The mean difference is significant at the .05 level.

a. Dependent Variable: PRS_Coherence.

c. Adjustment for multiple comparisons: Bonferroni.

3. Environment

Estimates ^a					
Environment	Mean	Std. Error	df	95% Confidence Interval	
				Lower Bound	Upper Bound
no people	3.899 ^b	1.596	331	.759	7.039
few people	3.456 ^b	1.596	331	.316	6.595
lots of people	3.137 ^b	1.596	331	-.003	6.276

a. Dependent Variable: PRS_Coherence.

b. Covariates appearing in the model are evaluated at the following values: Age = 38.34, Man_dummyvariable = .3103, NonW_dummyvariable = .1897, Couple_nochild_dummyvariable = .2931, Household_other_dummyvariable = .3621, Baseline stress = 7.48, Baseline hedonic tone = 13.70, Baseline energy = 12.12, Loneliness = 34.28, Trait social connectedness = 92.09, Connectedness_to_nature_average = 3.6404.

Pairwise Comparisons ^a							
(I) Environment	(J) Environment	Mean Difference (I-J)	Std. Error	df	Sig. ^c	95% Confidence Interval for Difference ^b	
						Lower Bound	Upper Bound
no people	few people	.443	.295	285.298	.403	-.268	1.155
	lots of people	.762 [*]	.295	285.298	.031	.051	1.474
few people	no people	-.443	.295	285.298	.403	-1.155	.268
	lots of people	.319	.295	284.579	.842	-.392	1.030
lots of people	no people	-.762 [*]	.295	285.298	.031	-1.474	-.051
	few people	-.319	.295	284.579	.842	-1.030	.392

Based on estimated marginal means

*. The mean difference is significant at the .05 level.

a. Dependent Variable: PRS_Coherence.

c. Adjustment for multiple comparisons: Bonferroni.

4. Timepoint * Environment

Estimates ^a					
Timepoint	Environment	Mean	Std. Error	df	95% Confidence Interval
					Lower Bound Upper Bound
Pre environment	no people	2.913 ^b	1.610	331	-.254 6.079
	few people	2.637 ^b	1.610	331	-.530 5.803
	lots of people	2.775 ^b	1.610	331	-.392 5.941
Post environment	no people	4.886 ^b	1.610	331	1.719 8.052
	few people	4.275 ^b	1.610	331	1.108 7.441
	lots of people	3.499 ^b	1.610	331	.332 6.665

a. Dependent Variable: PRS_Coherence.

b. Covariates appearing in the model are evaluated at the following values: Age = 38.34, Man_dummyvariable = .3103, NonW_dummyvariable = .1897, Couple_nochild_dummyvariable = .2931, Household_other_dummyvariable = .3621, Baseline stress = 7.48, Baseline hedonic tone = 13.70, Baseline energy = 12.12, Loneliness = 34.28, Trait social connectedness = 92.09, Connectedness_to_nature_average = 3.6404.

Pairwise Comparisons ^a								
Environment	(I) Timepoint	(J) Timepoint	Mean Difference (I-J)	Std. Error	df	Sig. ^c	95% Confidence Interval for Difference ^b	
							Lower Bound	Upper Bound
no people	Pre environment	Post environment	-1.973 [*]	.418	286.011	<.001	-2.796	-1.150
	Post environment	Pre environment	1.973 [*]	.418	286.011	<.001	1.150	2.796
few people	Pre environment	Post environment	-1.638 [*]	.417	284.579	<.001	-2.459	-.817
	Post environment	Pre environment	1.638 [*]	.417	284.579	<.001	.817	2.459
lots of people	Pre environment	Post environment	-.724	.417	284.579	.084	-1.545	.097
	Post environment	Pre environment	.724	.417	284.579	.084	-.097	1.545

Based on estimated marginal means

*. The mean difference is significant at the .05 level.

a. Dependent Variable: PRS_Coherence.

c. Adjustment for multiple comparisons: Bonferroni.

LMM output – Scope

Information Criteria ^a	
-2 Restricted Log Likelihood	1536.3256289
Akaike's Information Criterion (AIC)	1542.3256289
Hurvich and Tsai's Criterion (AICC)	1542.3990234
Bozdogan's Criterion (CAIC)	1556.7319840
Schwarz's Bayesian Criterion (BIC)	1553.7319840

The information criteria are displayed in smaller-is-better form.

a. Dependent Variable: PRS_Scope.

Fixed Effects

Type III Tests of Fixed Effects^a

Source	Numerator df	Denominator df	F	Sig.
Intercept	1	62.300	1.478	.229
Timepoint	1	285.297	242.788	<.001
Environment	2	285.296	9.153	<.001
Timepoint * Environment	2	285.296	3.398	.035
Age	1	48.745	.593	.445
Man_dummyvariable	1	46.811	3.209	.080
NonW_dummyvariable	1	47.653	.023	.880
Couple_nochild_dummyvariable	1	46.948	.744	.393
Household_other_dummyvariable	1	46.898	.006	.939
Baseline_stress	1	48.251	.019	.892
Baseline_hedonic_tone	1	112.723	.398	.529
Baseline_energy	1	49.532	1.189	.281
Loneliness	1	48.641	.197	.659
Trait_social_connectedness	1	46.984	1.315	.257
Connectedness_to_nature_average	1	46.690	.356	.554

a. Dependent Variable: PRS_Scope.

2. Timepoint

Estimates^a

Timepoint	Mean	Std. Error	df	95% Confidence Interval	
				Lower Bound	Upper Bound
Pre environment	1.325 ^b	1.346	331	-1.323	3.973
Post environment	4.577 ^b	1.346	331	1.929	7.225

a. Dependent Variable: PRS_Scope.

b. Covariates appearing in the model are evaluated at the following values: Age = 38.34, Man_dummyvariable = .3103, NonW_dummyvariable = .1897, Couple_nochild_dummyvariable = .2931, Household_other_dummyvariable = .3621, Baseline stress = 7.48, Baseline hedonic tone = 13.70, Baseline energy = 12.12, Loneliness = 34.28, Trait social connectedness = 92.09, Connectedness_to_nature_average = 3.6404.

Pairwise Comparisons^a

(I) Timepoint	(J) Timepoint	Mean Difference (I-J)	Std. Error	df	Sig. ^c	95% Confidence Interval for Difference ^b	
						Lower Bound	Upper Bound
Pre environment	Post environment	-3.252 [*]	.209	285.297	<.001	-3.663	-2.841
Post environment	Pre environment	3.252 [*]	.209	285.297	<.001	2.841	3.663

Based on estimated marginal means

*. The mean difference is significant at the .05 level.

a. Dependent Variable: PRS_Scope.

c. Adjustment for multiple comparisons: Bonferroni.

3. Environment

Estimates^a

Environment	Mean	Std. Error	df	95% Confidence Interval	
				Lower Bound	Upper Bound
no people	3.488 ^b	1.350	331	.831	6.144
few people	2.972 ^b	1.350	331	.316	5.628
lots of people	2.394 ^b	1.350	331	-.262	5.050

a. Dependent Variable: PRS_Scope.

b. Covariates appearing in the model are evaluated at the following values: Age = 38.34, Man_dummyvariable = .3103, NonW_dummyvariable = .1897, Couple_nochild_dummyvariable = .2931, Household_other_dummyvariable = .3621, Baseline stress = 7.48, Baseline hedonic tone = 13.70, Baseline energy = 12.12, Loneliness = 34.28, Trait social connectedness = 92.09, Connectedness_to_nature_average = 3.6404.

Pairwise Comparisons^a

(I) Environment	(J) Environment	Mean Difference (I-J)	Std. Error	df	Sig. ^c	95% Confidence Interval for Difference ^b	
						Lower Bound	Upper Bound
no people	few people	.516	.256	285.529	.134	-.100	1.132
	lots of people	1.093 [*]	.256	285.529	<.001	.478	1.709
	lots of people	-.516	.256	285.529	.134	-1.132	.100
few people	lots of people	.578	.255	284.832	.074	-.038	1.193
lots of people	no people	-1.093 [*]	.256	285.529	<.001	-1.709	-.478
	few people	-.578	.255	284.832	.074	-1.193	.038

Based on estimated marginal means

*. The mean difference is significant at the .05 level.

a. Dependent Variable: PRS_Scope.

c. Adjustment for multiple comparisons: Bonferroni.

4. Timepoint * Environment

Estimates^a

Timepoint	Environment	Mean	Std. Error	df	95% Confidence Interval	
					Lower Bound	Upper Bound
Pre environment	no people	1.670 ^b	1.362	331	-1.010	4.350
	few people	1.153 ^b	1.362	331	-1.527	3.833
	lots of people	1.153 ^b	1.362	331	-1.527	3.833
Post environment	no people	5.305 ^b	1.362	331	2.625	7.985
	few people	4.791 ^b	1.362	331	2.111	7.471
	lots of people	3.636 ^b	1.362	331	.956	6.315

a. Dependent Variable: PRS_Scope.

b. Covariates appearing in the model are evaluated at the following values: Age = 38.34, Man_dummyvariable = .3103, NonW_dummyvariable = .1897, Couple_nochild_dummyvariable = .2931, Household_other_dummyvariable = .3621, Baseline stress = 7.48, Baseline hedonic tone = 13.70, Baseline energy = 12.12, Loneliness = 34.28, Trait social connectedness = 92.09, Connectedness_to_nature_average = 3.6404.

Pairwise Comparisons^a

Environment	(I) Timepoint	(J) Timepoint	Mean Difference (I-J)	Std. Error	df	Sig. ^c	95% Confidence Interval for Difference ^b	
							Lower Bound	Upper Bound
no people	Pre environment	Post environment	-3.635 [*]	.362	286.221	<.001	-4.347	-2.923
	Post environment	Pre environment	3.635 [*]	.362	286.221	<.001	2.923	4.347
few people	Pre environment	Post environment	-3.638 [*]	.361	284.832	<.001	-4.349	-2.927
	Post environment	Pre environment	3.638 [*]	.361	284.832	<.001	2.927	4.349
lots of people	Pre environment	Post environment	-2.483 [*]	.361	284.832	<.001	-3.194	-1.772
	Post environment	Pre environment	2.483 [*]	.361	284.832	<.001	1.772	3.194

Based on estimated marginal means

*. The mean difference is significant at the .05 level.

a. Dependent Variable: PRS_Scope.

c. Adjustment for multiple comparisons: Bonferroni.

LMM output – Compatibility

Information Criteria ^a	
-2 Restricted Log Likelihood	1496.1356689
Akaike's Information Criterion (AIC)	1502.1356689
Hurvich and Tsai's Criterion (AICC)	1502.2090634
Bozdogan's Criterion (CAIC)	1516.5420240
Schwarz's Bayesian Criterion (BIC)	1513.5420240

The information criteria are displayed in smaller-is-better form.

a. Dependent Variable:
PRS_Compatibility.

Fixed Effects

Type III Tests of Fixed Effects ^a				
Source	Numerator df	Denominator df	F	Sig.
Intercept	1	61.683	.599	.442
Timepoint	1	284.751	696.274	<.001
Environment	2	284.750	9.002	<.001
Timepoint * Environment	2	284.750	8.635	<.001
Age	1	48.129	.005	.946
Man_dummyvariable	1	46.249	.023	.880
NonW_dummyvariable	1	47.069	.468	.497
Couple_nochild_dummyvariable	1	46.383	.113	.738
Household_other_dummyvariable	1	46.334	.402	.529
Baseline_stress	1	47.650	.043	.836
Baseline_hedonic_tone	1	107.435	.096	.757
Baseline_energy	1	48.893	.237	.629
Loneliness	1	48.028	.013	.910
Trait_social_connectedness	1	46.417	.000	.988
Connectedness_to_nature_average	1	46.132	.714	.403

a. Dependent Variable: PRS_Compatibility.

2. Timepoint

Estimates ^a					
Timepoint	Mean	Std. Error	df	95% Confidence Interval	
				Lower Bound	Upper Bound
Pre environment	1.036 ^b	1.257	331	-1.438	3.509
Post environment	6.240 ^b	1.257	331	3.767	8.714

a. Dependent Variable: PRS_Compatibility.

b. Covariates appearing in the model are evaluated at the following values: Age = 38.34, Man_dummyvariable = .3103, NonW_dummyvariable = .1897, Couple_nochild_dummyvariable = .2931, Household_other_dummyvariable = .3621, Baseline stress = 7.48, Baseline hedonic tone = 13.70, Baseline energy = 12.12, Loneliness = 34.28, Trait social connectedness = 92.09, Connectedness_to_nature_average = 3.6404.

Pairwise Comparisons ^a							
(I) Timepoint	(J) Timepoint	Mean Difference (I-J)	Std. Error	df	Sig. ^c	95% Confidence Interval for Difference ^b	
						Lower Bound	Upper Bound
Pre environment	Post environment	-5.205 [*]	.197	284.751	<.001	-5.593	-4.816
Post environment	Pre environment	5.205 [*]	.197	284.751	<.001	4.816	5.593

Based on estimated marginal means

*. The mean difference is significant at the .05 level.

a. Dependent Variable: PRS_Compatibility.

c. Adjustment for multiple comparisons: Bonferroni.

3. Environment

Estimates^a

Environment	Mean	Std. Error	df	95% Confidence Interval	
				Lower Bound	Upper Bound
no people	4.101 ^b	1.261	331	1.620	6.582
few people	3.725 ^b	1.261	331	1.244	6.206
lots of people	3.087 ^b	1.261	331	.606	5.568

a. Dependent Variable: PRS_Compatibility.

b. Covariates appearing in the model are evaluated at the following values: Age = 38.34, Man_dummyvariable = .3103, NonW_dummyvariable = .1897, Couple_nochild_dummyvariable = .2931, Household_other_dummyvariable = .3621, Baseline stress = 7.48, Baseline hedonic tone = 13.70, Baseline energy = 12.12, Loneliness = 34.28, Trait social connectedness = 92.09, Connectedness_to_nature_average = 3.6404.

Pairwise Comparisons^a

(I) Environment	(J) Environment	Mean Difference (I-J)	Std. Error	df	Sig. ^c	95% Confidence Interval for Difference ^b	
						Lower Bound	Upper Bound
no people	few people	.376	.242	284.981	.362	-.206	.958
	lots of people	1.014 [*]	.242	284.981	<.001	.432	1.596
few people	no people	-.376	.242	284.981	.362	-.958	.206
	lots of people	.638 [*]	.241	284.288	.026	.057	1.219
lots of people	no people	-1.014 [*]	.242	284.981	<.001	-1.596	-.432
	few people	-.638 [*]	.241	284.288	.026	-1.219	-.057

Based on estimated marginal means

*. The mean difference is significant at the .05 level.

a. Dependent Variable: PRS_Compatibility.

c. Adjustment for multiple comparisons: Bonferroni.

4. Timepoint * Environment

Estimates^a

Timepoint	Environment	Mean	Std. Error	df	95% Confidence Interval	
					Lower Bound	Upper Bound
Pre environment	no people	1.036 ^b	1.273	331	-1.468	3.539
	few people	1.053 ^b	1.273	331	-1.451	3.556
	lots of people	1.018 ^b	1.273	331	-1.485	3.522
Post environment	no people	7.167 ^b	1.273	331	4.663	9.671
	few people	6.398 ^b	1.273	331	3.894	8.901
	lots of people	5.156 ^b	1.273	331	2.653	7.660

a. Dependent Variable: PRS_Compatibility.

b. Covariates appearing in the model are evaluated at the following values: Age = 38.34, Man_dummyvariable = .3103, NonW_dummyvariable = .1897, Couple_nochild_dummyvariable = .2931, Household_other_dummyvariable = .3621, Baseline stress = 7.48, Baseline hedonic tone = 13.70, Baseline energy = 12.12, Loneliness = 34.28, Trait social connectedness = 92.09, Connectedness_to_nature_average = 3.6404.

Pairwise Comparisons^a

Environment	(I) Timepoint	(J) Timepoint	Mean Difference (I-J)	Std. Error	df	Sig. ^c	95% Confidence Interval for Difference ^b	
							Lower Bound	Upper Bound
no people	Pre environment	Post environment	-6.131 [*]	.342	285.669	<.001	-6.805	-5.458
	Post environment	Pre environment	6.131 [*]	.342	285.669	<.001	5.458	6.805
few people	Pre environment	Post environment	-5.345 [*]	.341	284.288	<.001	-6.017	-4.673
	Post environment	Pre environment	5.345 [*]	.341	284.288	<.001	4.673	6.017
lots of people	Pre environment	Post environment	-4.138 [*]	.341	284.288	<.001	-4.810	-3.466
	Post environment	Pre environment	4.138 [*]	.341	284.288	<.001	3.466	4.810

Based on estimated marginal means

*. The mean difference is significant at the .05 level.

a. Dependent Variable: PRS_Compatibility.

c. Adjustment for multiple comparisons: Bonferroni.

Appendix 29. Chapter 6 qualitative analysis framework matrix

SOCIAL COMFORT IN LESS CROWDED SPACES								
Ppt no.	Age and gender	Pseudo nym	Feeling socially connected	People watching	Focus diverted to people	Availability of seating	Reflection of normality	Preference for a few people
65	Woman, 37	Tamala			in environment 2 where there were fewer people, I was taking more in of the actual park and had more time to look at the people there	Whereas with environment 2 there was available benches and places I could go and set up my own space.		
66	Woman 36	Isla					I think maybe some people you will feel more real. If its empty on a sunny day, its not real. A few people is a real world and you can expect	
67	Man, 43	Heath	environment 2 would be my preference given that theres a bit of human interaction or potential for human	the more people there are, the more time you spend people watching.	whereas when it was more people heavy, I was focusing on the people because they were dominating			environment 2 would be my preference given that theres a bit of human interaction or potential for human interaction
68	Man, 27	River						I would prefer the one that doesn't have too many people
69	Man, 41	Aaron					But if 2 or 3 people are around I want to be there. Also, I think its VR but I could relate to my everyday life and what its like	For the third one, the natural environment was there but people were around. From what I think, I was there to connect with nature but some people are around so it feels
70	Woman, 39	Holly	so the middle one was nice to hear some voices and see a few people				But you want a bit of atmosphere so I think the middle one was my favourite. Like if it was a real life situation then yeah the middle one.	But you want a bit of atmosphere so I think the middle one was my favourite. Like if it was a real life situation then yeah the middle one.

Appendix 30. Chapter 6 codebook

Theme 1. Social comfort in less crowded spaces		
Code	Description	Count
Feeling socially connected	Descriptions of feeling more socially connected when a few people are present in a space	18
People watching	Descriptions of intended activity of people watching	24
Focus diverted to people	Attention is drawn to the people when they are present in the space	19
Availability of seating	Ability to find seating when fewer people are present	6
Reflection of normality	Preference for a virtual environment which reflects normality, day-to-day life and experiences, familiarity with a space	18
Preference for a few people	Description of preference for environment 2 (a few people present)	32

Theme 2. Experience of being alone		
Code	Description	Count

Escapism	Being in urban greenspaces can allow for escapism and to be away from the world, people, stress	10
Calmness and relaxation	Relaxation as a reason to visit, increased relaxation when no people are present	26
Wanting to be alone	Preference to be alone when visiting urban greenspaces	6
Boredom when alone	Being alone in an urban greenspace can be boring, there is nothing going on or anything to look at	8
Vulnerability being alone	Feeling vulnerable when alone in urban greenspace, wary of danger	11
Attention drawn to nature	More attention is placed on nature features in the urban greenspace when there are no people present	26
Feeling observed	Feeling watched and exposed when alone in urban greenspace	3

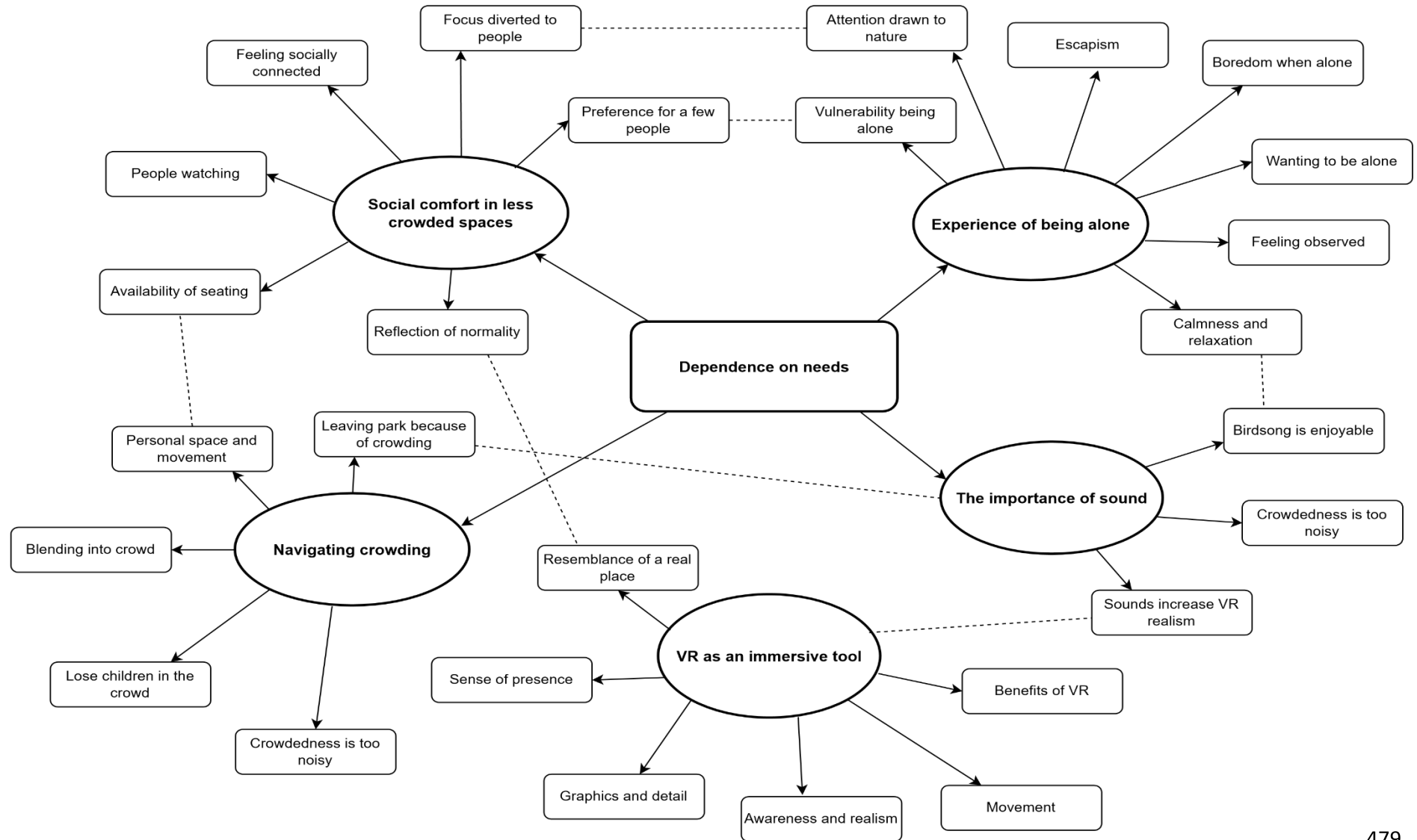
Theme 3. Navigating crowding		
Code	Description	Count
Personal space and movement	Freedom to move, needing personal space, importance in position of other people	20
Leaving park because of crowding	Description of wanting to leave urban greenspace if too crowded	8
Blending into crowd	Being able to hide amongst people, less attention drawn to self	4
Lose children in the crowd	Worry in losing children if space is too crowded	1
Crowdedness is noisy	The dislike for noisiness which comes from increased amounts of people in a space	16

Theme 4. The importance of sound		
Code	Description	Count
Sounds increase VR realism	Environments feel more real and immersive with added sound	9
Birdsong is enjoyable	Awareness of birdsong, happiness in hearing birdsong	13
Crowdedness is too noisy	Dislike for noise created by increased amount of people present	16

Theme 5. VR as an immersive tool		
Code	Description	Count

Sense of presence	Feeling of being transported to a different world, environment being realistic enough	10
Graphics and detail	Opinions regarding graphical and technical quality of VR	18
Awareness and realism	Viewing the environments as realistic whilst still realising they're virtual	11
Movement	Physical movement wearing headset, inability to walk, 360-degrees	6
Resemblance of a real place	Comparisons made between virtual environment and a familiar real environment	3
Benefits of VR	VR as a helpful tool for people, a replacement for visiting nature	3

Appendix 31. Chapter 6 thematic map



Appendix 32. Dissemination

As well as the included publications, the findings in this thesis have been disseminated through presentations at numerous local and international conferences, seminars, and meetings. This was in order to exchange the knowledge learnt from these studies, learn from other researchers, and create impact. Findings from this thesis have been presented via oral and poster presentations at three international conferences: The International Conference on Environmental Psychology (ICEP) (2023), and the International Association of People-Environment Studies Conferences (IAPS) (2022 and 2024). At these large conferences, my research was visible to leading scholars across numerous disciplines including but not limited to environmental psychology, public health, geography, and architecture. In addition to these, this research has also been presented orally at local conferences including the SWDTP Student Conference 2023, and the UWE College of Health Science and Society Postgraduate Researcher Conference 2024. Here the research was presented to audiences predominantly from health and social science disciplines. Finally, the findings from this thesis have been presented at internal UWE meetings and seminar series including the Centre for Public Health and Wellbeing meetings and research showcase (2023), and at a greenspace and health seminar series in the university. All efforts for dissemination have been in order to increase the visibility of the findings of this thesis and impact urban greenspace and well-being research and policies.