Adapting interfaces to induce behaviour change and mitigate the negative effects of interruptions in safety critical healthcare settings.

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Abstract

Due to the fast-paced, dynamic, and sometimes unpredictable nature of the environment's healthcare professionals work within, it is inevitable that task interruptions will occur. Such clinical task interruptions are consistently cited as a contributing factor to the manifestation of clinical errors. Various theoretical approaches to exploring task interruptions and their varying characteristics have provided valuable insights into their role in task performance (positive and negative). Furthermore, applied research has revealed the complex nature of trying to understand task interruptions within safety critical, multifaceted working environments such as healthcare. Bridging an evidential gap in the literature with theoretically informed studies using developed tasks (primary and interrupting) with a level of ecological validity is an important step to understanding the nature of task interruptions in healthcare and can guide work towards developing interventions that are beneficial towards appropriate handling of task interruptions in healthcare.

Through an exploratory study and a series of six experiments the following thesis develops a more ecological primary (procedural memory drug administration task) and interruption task (clinical decision-making task) that mimics those likely to be used daily by healthcare professionals. The parameters of the task and performance are explored through interruption manipulations that mimic those healthcare professionals are likely to experience (e.g., including interruption complexity, frequency, and source), whilst also considering unique characteristics of the healthcare environment (e.g., interruption urgency, and emotional valance of interruption). Key findings include positive emotionally valanced interruptions increasing error rates, urgent interruptions have more of a profound effect on performance and reducing information access costs significantly reduces task errors following an interruption. Findings using experimental tasks progresses the healthcare interruption literature in providing novel insight into the nature of task interruptions in healthcare, and the potential role the ecological nature the tasks may have on performance. Furthermore, adopting a different approach to explore task interruptions in healthcare allows for the exploration of novel interventions and their utility in mitigating the negative effects of interruptions. Interventions are explored in the final experiment, whereby the cost of accessing information is manipulated to induce an implicit cognitive behavioural change whereby such behavioural changes may be protective to the negative effects of task interruptions. Taken together, this work has made significant contributions to the current literature through extrapolating results to the context that the experiments are meant to probe (e.g., healthcare medication administration), thus providing

additional utility when considering designs to mitigate the profound effects of task interruptions that are representative of that context.

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Chapter 1: Justification for Research

Interruptions are particularly prevalent in clinical settings due to the constant, busy, chaotic nature of hospitals. These interruptions have been recognised as being a contributing factor to errors made in clinical contexts, which is a matter of concern when considering that interruptions are an expected feature of working in this setting (Werner & Holden, 2015; Hohenhaus & Powell, 2008). Workers in this field depend upon the successful interaction of multiple work system factors (e.g., technology, patient factors, healthcare staff, the organisation) to ensure suitable treatment and that patient safety is maintained. Empirical evidence on the contribution of interruptions to medication administration (particularly during the pre-administration stage) is limited, however, several observational research exists in this domain which state that medication administration is at a particular risk from interruption-related error (e.g., Biron & Loiselle, 2009; Blandford et al., 2016). Thus, this research aims to increase knowledge on the interruption factors that may contribute to administration errors using novel experimental tasks designed to explore task interruptions within this context. Task interruptions almost universally impair performance of an interrupted task, irrespective of the type of task being interrupted, or the applied context in which interruptions are likely to occur (Trafton & Monk, 2007). How interruptions are defined varies across the literature and is often constrained to the specific aims of the research. Here, interruptions are defined as the reallocation of cognitive resources to a secondary stimulus, which requires the individual to shift their attention away from the primary task at hand (Altmann & Trafton, 2002). Numerous experimental studies within the domain of cognitive science have attempted to explain how different cognitive processes are affected by task interruptions, and how such observed disruptive effects can potentially be mediated by the characteristics of the interruption which may include (but not limited too); complexity (Cades, Werner & Trafton, 2008; Gillie & Broadbent, 1989; Hodgetts & Jones, 2006), frequency (Lee & Duffy, 2015; Zijlstra et al, 1999), and source (Ratwani, Andrews, Sousk & Trafton, 2008; Ratwani & Trafton, 2010). The exploration of task interruptions in an applied context such as healthcare, often focuses on its contributory role in the manifestation of clinical errors, which in turn can potentially inform novel interventions to mitigate observed negative effects.

It is evident from the psychological and healthcare literature surrounding task interruptions that both domains often explore task interruptions through a different lens. Psychological studies often adopt a controlled experimental method to explain non-observable characteristics of task interruptions and the underlying effects these may have on human cognition and performance (e.g., Altmann, Trafton & Hambrick, 2017). Healthcare studies usually take a more qualitative methodological standpoint, often exploring the observable characteristics of clinical task interruptions (e.g., Filer, Beringuel, Frato, Anthony & Saenyakul, 2017; Laustsen & Brahe, 2018) within the healthcare workplace to provide insight into the possible contextual relationship they may have with clinical errors. It may be that the use of multiple methods could lead to more validated insights relating to task interruptions in healthcare, thus allowing for more context orientated interventions to be explored. For example, Blandford et al (2016) utilised a mixed methods approach to explore the type of errors that may impact patient safety during the use of smart pumps. The authors first quantified observations of the prevalence and types of clinical errors that occurred, and then presented the results to healthcare staff in focus groups to develop healthcare practises.

While all approaches offer valuable insights into the role of task interruptions and capture the complex nature of trying to understand interruptions in dynamic working environments such as healthcare, there appears to be a lack of a direct link between theoretically informed findings on the characteristics of clinical task interruptions that could underlie their disruptiveness. Bridging this gap with theoretically informed studies using tasks (primary and interrupting) with a level of ecological validity is thus a very important step for both fields. Only then, should we consider possible methods to alleviate disruptive effects. Some experimental studies have attempted to generalise their findings to healthcare settings, even more so when the focus of research is on tasks that best represent well-learnt skills and procedures (such as procedural memory: Altmann et al, 2014) assumed to mimic tasks/subtasks in some settings. While such tasks may represent elements (e.g., a sequential procedure) of clinical tasks that follow similar processes (e.g., medication administration), both the primary task and interruption task in many of these studies lack domain-specific content that would better capture the varying properties such clinical tasks may have (McCurdie, Sanderson & Aitken, 2017). Representative experimental designs would allow for further generalisations of findings to the environment in which experiments are intended to explore. Rather than overcontrolling experimental conditions, allowing for a level of complexity, novelty and diversity would better represent individuals' functional behaviours in the natural environment (Ajaujo, Davids & Passos, 2007).

While some clinical tasks are procedural in nature, the nature of the steps required are often different (in terms of complexity, urgency, and other factors) compared to the laboratory-based tasks used. Likewise, task interruptions during clinical tasks may also vary in similar characteristics, where by interruptions may vary significantly by their frequency (Craker et al, 2017; Spooner, Corley, Chaboyer, Hammond & Fraiser, 2015), mode of communication (Biron, Loiselle & Lavoie-Tremblay, 2009; Brixey, Walji, Zhang, Johnson & Turley, 2004) and the amount of cognitive resources needed to successfully complete (Magrabi, Li, Day & Coiera, 2010; Sasangohar, Donmez, Easty & Trbovich, 2017).

Healthcare interventions that are aimed at reducing clinical task interruptions during the medication administration process have been shown to have limited effectiveness when implemented (Raban & Westbrook, 2014). There have also been attempts at utilising technology to mitigate errors caused by interruptions through the proposition of an improvement of the medication process, exclusion of situational risk factors, and error interception (Moyen, Camire & Stelfox, 2008). Error mitigation using technology that improves the medication process, whilst at times is successful in limiting some human medication errors, may enforce the creation of other errors (Wickens, 1992). Furthermore, such interventions are usually designed to reduce cognitive load of the human operator during clinical tasks (and thus reduce the potential for error), but often designs do not account for situational factors such as task interruptions during the use of these technological interventions (Ash, Berg & Coiera, 2004; Collins et al, 2007).

Whilst it may seem that healthcare technology may be a possible solution for error mitigation in the face of task interruptions, more research is needed in understanding the characteristics of healthcare task interruptions that may potentially increase or decline the likelihood of errors occurring. Such factors include understanding how healthcare professionals' cognition is affected by clinical task interruptions, which may enhance and/or extend the explanatory power of current interruption theories and models, and in turn potentially inform more robust, cost-effective technological designs, which offer flexible ways to effectively handle such interruptions within dynamic safety critical work settings.

This thesis draws on previous research from both the psychological and healthcare literature and proposes the use of a novel theoretically informed experimental design, employing a procedural memory drug administration primary task that mimics a similar task used in healthcare settings. Furthermore, the parameters of the task will be explored through interruption manipulations that mimic those that healthcare professionals are likely to experience on a regular basis including interruption complexity, frequency, and mode of communication. Traditional experimental tasks used to explore task interruptions have provided useful information in understanding interruption effects, but the translation to clinical practice is still unclear. The use of more realistic yet controllable tasks will enhance the application of the findings reported here, inform current theories and models of task interruptions in an applied context, and lead the way for evidence-based interventions to mitigate the profound effects such clinical task interruptions have.

Overall Research Question and Aims

This PhD addresses some of the limitations identified in previous research on task interruptions in safety critical healthcare settings, which in turn will further extend our current understanding of task interruption and allow for further development of our understanding related to healthcare errors and interventions to mitigate such effects. In consideration of these limitations, the aims of this PhD are as follows.

- Explore the characteristics and effects of clinical task interruptions within a UK safety critical healthcare setting using a novel healthcare questionnaire. The questionnaire was developed to explore differences between interruptions and distractions and the key characteristics and impact these may have on healthcare professionals working with an emergency critical care setting.
- Building on past research and paradigms, develop a contextually familiar healthcare experimental primary and interruption task that mimics elements of a specific healthcare procedure.
- Using the created tasks, investigate the varying impacts that commonly cited interruption characteristics (complexity, frequency, and interruption source) have on performance.
- Investigate the effect of task interruptions that vary in characteristics that are unique to safety critical healthcare environments (emotivity and urgency).
- Explore how a novel computer-based intervention may alleviate the negative effects of task interruptions.

To help address the aims of the PhD the following research questions were developed.

- What are the characteristics and perceived impact of task interruptions by healthcare professionals in a UK hospital setting?
- To what extent does the context of the primary and interruption task exaggerate the impact of commonly cited interruption characteristics (complexity, frequency, and interruption source) on performance?

- What are the effects of unique characteristics of safety critical healthcare task interruptions (e.g., urgency and emotivity) on performance?
- Can computer-based interventions alleviate the negative effects of task interruptions through encouraging behavioural changes?

Chapter 2: Literature Review

The following literature review aims to provide an extended contextual insight into task interruptions, and the role they have within a healthcare setting. To achieve this and given the potential detrimental impact of errors within a healthcare system, it is vital to understand the manifestation of such errors and the role of interruptions more generally. The literature reviewed here first discusses approaches to understanding errors and why they might occur, prior to exploring the magnitude of errors within the medication process. The review will then focus on the contributing role of task interruptions and influencing factors on medication errors, through exploring experimental frameworks. The final part of the review considers the current literature on interventions aimed at mitigating the negative effects of task interruptions. Gaps in current understanding of factors leading to errors and mitigation strategies is also discussed.

Human Error: A General Perspective

The study of human error(s) traditionally takes one of two approaches: a person-centred approach or systems approach. The person-centred approach often puts the individual at the root cause of the error with the assumption that errors arise mainly from abnormal mental processes of the individual (e.g., forgetfulness, lack of motivation, carelessness; Reason, 2000). Such an approach is often viewed as 'The Bad Apple Theory' of human error (Dekker, 2002), with the assumption that human error is the cause of most accidents, the systems in which these errors occur are safe, and humans are the main threat to organisational safety. Therefore, the system needs protection from unreliable humans (Dekker, 2002).

The person-centred approach is evident within a healthcare setting, where error being attributed to the individual may create a culture where individual blame appears to be the easiest solution (Reason, 2000). Such an approach is still evident across the healthcare literature (e.g., Anderson, 2016; Dekker & Leveson, 2014; Holden, 2009; Levitt, 2014), despite a substantial amount of research on errors adopting a systems approach (e.g., Carayon, Wetterneck, Rivera-Rodriguez, Hundt, Hoonakker, Holden & Gurses, 2014; Mitchell, Williamson & Molesworth, 2016). It was argued by Holden (2009), that by attributing the cause of an error to the individual, it may potentially supply an inadequate understanding of the error itself given the multifactorial, and complex nature of causation, particularly within a complex system such as healthcare. Furthermore, such attributions may not be that meaningful for a healthcare organisation, as it does not ensure effective designs can be implemented to protect the system from such errors in the future, and in a healthcare context, ensure patient safety is supported.

In contrast to the person-centred approach, a systems approach aims to identify the errors that can occur within each level of that system (e.g., individual level, organisational level, workplace conditions), which in turn allows one to generate an understanding of the contributing role each factor plays in the error itself (Reason, 1995). The human error in a systems approach is viewed as the result of a failure in the logical processes within a system (e.g., cognitive, operational; Woods, Dekker, Cook, Johannesen & Sarter, 2010). By adopting this approach, research still shows that many causes of errors are often initiated by the individual, however, it is often the result of several contributing factors including both individual characteristics and situational factors (Lawton, McEachan, Giles, Sirriyeh, Watt & Wright, 2012). A systems approach allows for a wider contextual understanding of errors, and the identification of contributing factors – such as task interruptions – to the errors, which paves the way for more research into each contributing factor and in turn inform safer system designs. Table 1 provides a summative comparison of the two approaches.

Table 1: Comparison between the person-centred and systems approach to human error in healthcare. Adapted from: Dekker (2011)

Human Error as a Medical Competence Problem (Person-centred)	**Human Error as an Organisational Problem (Systems)**
Human error is the cause.	Human error is the result of deeper organisational issues.
Human error may be the conclusion of an investigation.	Human error is the starting point for investigation.
Human error is itself a useful target for intervention.	Meaningful intervention lies in the factors that help produce human expertise and error.
Healthcare is a safe environment; It needs protection from unreliable medical staff.	A healthcare environment is not inherently safe. People can create safety by integration of multiple goals, pressures, constraints, and complexities.

General and context specific error classification models and theories, provide insightful accounts of various types of errors, how they may arise, and how they may result in failure of an individual's cognitive process. By adopting an information processing approach and building upon early cognitive theories and research around human performance, Reason (1990) proposed a Generic Error-Modelling System (GEMS). According to GEMS, an unsafe act made by the individual could be the result of either an intended or unintended action.

Mistakes and violations are the result of an intended action that deviates from what may be considered as the more appropriate action. Mistakes arise at the planning level of an action, resulting in an intentional implementation of the wrong action due to a planning failure (e.g., Doctor disconnecting chest drains with non-sterile gloves when the choice is sterile or none-sterile gloves). Such mistakes may arise due to the application of a rule that has been misinformed by prior experience (e.g., If there are gloves available then they must be sterile; Rule-based mistake; Tallentire, Smith, Skinner & Cameron, 2012). They may also occur if the situation and/or environment is unfamiliar creating a dissonance in a previously correct procedure, which in turn may result in over/under-confidence in perceived professional capabilities (e.g., Sterile gloves are not available, so non-sterile gloves will be ok in this situation; Knowledge-based mistake; Embrey, 2005). Violations on the other hand are deviations from appropriate and expected procedures and rules either deliberately (e.g., knowingly using a non-sterile glove) or unintentionally (e.g., unknowingly using a non-sterile glove; Stanton & Salmon, 2009).

Unintended actions are skill-based errors that arise during the execution or storage stage of an action. According to GEMS, there are two skill-based errors that may arise; slips and lapses. Slips are often associated with attentional failures that occur during the execution of a task and may present in several different ways as outlined below.

- Omission – omitting a planned step in the skill.
- Intrusion – an inappropriate action which may be part of another skill.
- Repetition – repeating an already performed action.
- Mis-ordering – wrong sequence of actions.
- Mistiming – wrong time for the correct action.
- Lapses are associated with memory failures that occur during the storage stage of an action and may present in one of the following ways.
- Omission or delay in doing a planned action.
- Forgetting of information (Fortune, Davis, Hanson & Phillips, 2012).

Each of the error types are the result of an unsafe act occurring and may represent the individual's contribution to the error itself, however errors are also influenced by the systemic conditions in which the error is likely to arise. The GEMS also distinguishes between active and latent failures, with active failures representing the originators of the accident (workers), and latent failures representing other contributing system factors (O'Connor, O'Dea, and Melton, 2007). However, it has been suggested that to maximize the designing out of errors within a certain workplace environment, context specific taxonomies are needed.

Mitchell, Williamson, and Molesworth (2016) used a Human Factors (HF) classification framework to find common adverse events within healthcare settings, and the extent to which these events may be attributed to either skill-based, rule-based, or knowledge-based errors. Furthermore, the study also identified an extensive range of precursor and contributing factors, further highlighting the complexity and multifaceted nature of errors within the healthcare environment. From their analysis of 498 clinical incidents, the authors report that staff action was the most frequent precursor to clinical incidents (e.g., communication, misdiagnosis, medication issue), with such incidents related to specific error types (e.g., skill-based errors related to misdiagnosis, rule-based errors with administration of medication). Furthermore, organisational (e.g., supervision, staffing issues, work pressure) and patient factors (e.g., fatigue, physical health, communication issues) were the most often reported contributing factors to clinical incidents. Whilst this study takes a more general approach to classifying errors in healthcare settings, quite often healthcare studies narrow the focus to more specific errors such as those involving: diagnostic errors (e.g., Singh, Giardina, Meyer, Forjuoh, Reis & Thomas, 2013), surgery failures (e.g., Catchpole, Giddings, de Leval, Peck, Godden, Utley, Gallivan, Hirst & Dale, 2006), and, hypertension care related (e.g., Lee, Cho & Bakken, 2010). Whilst such research is informative on error classifications in these contexts, quite often they do not supply insights into events – such as interruptions - that may contribute to such errors.

Using the GEMS (Reason, 1990), Zhang, Patel, Johnson and Shortliffe (2004) proposed a cognitive taxonomy to categorise major medication errors, the cognitive processes involved in these errors, why they occur, and how interventions may mitigate each type. For example, cognitive slips during medication administration may arise through either the execution of an action, or the evaluation of that action. If a doctor must attend an urgent matter during medication administration and afterwards returns to a different patient (goal slip), this would fall under the category of execution slip. If a flashing perceptual alarm on a medical device is processed as non-critical when it is critical (interpretation slip), this would be considered as an evaluation slip. Each example given may be associated with different processes (e.g., cognitive, behavioural, organisational), with the execution slip example may possibly be due to a loss in goal activation or cognitive overload. The evaluation slip may be associated with a lack of knowledge or training, or again cognitive overload. Whilst such a model serves its purpose in supplying a more context specific taxonomy of errors, and indicates the processes involved in such errors, it does not explain how certain factors may (or may not) impact these processes. For example, interruptions during a medication process (ordering, prescribing, administering) may delay the medication process (McGillis Hall, Pedersen & Fairley, 2010) and potentially increase the likelihood of an error occurring – such as a goal slip - due to increased cognitive demands (Li, Magrabi & Coiera, 2011).

Studies have also utilised HF models of errors in an attempt to describe contributing factors to medication errors including; Medmarx (National Coordination Council for Medication Error Reporting and Prevention (NCC MERP: 2001) which categorises medication errors based on the severity of outcome to patients (e.g., Hicks, Becker, Krenzischeck & Beyea, 2004; Hicks, Cousins & Williams, 2004), and the Edinburgh taxonomy (Busse & Wright, 2000) which typifies medication errors based on both cognitive and behavioural factors (Thomadsen, 2012). Whilst the Medmarx considers some contributing factors, such factors along with the error classifications, constitutes only a small number of categories that represents a broad range of processes and contributing factors. When used, the Medmarx is used across all healthcare contexts where medical tasks vary in several aspects (complexity, procedure, cognitive processes involved, healthcare professional responsibility), and environments impose differential demands (time constraints, patient intake, staffing levels). This makes it particularly difficult to infer the role of each contributing factor and cognitive processes affected given no option for elaboration (Brixey, Johnson & Zhang, 2002). Such criticism also applies to the Edinburgh taxonomy, in which the classifications of contributing factors are too specific (e.g., presence of student, unit busy, turning the patient; Thomadsen, 2012).

Whilst the above medication error taxonomies view such errors as general across all healthcare contexts, a specific focus in more safety critical healthcare setting is evident in the literature, where such errors appear to be more prominent and more likely to result in adverse outcomes. Kopp, Erstad, Allen, Theodorou & Priestley (2006) investigated the prevalence and preventability of medication errors in ICU using a prospective observational design, in that participants were selected and observed in the present until a medication error occurred in the future. 110 potential medication errors were identified, of which the researchers could intercept 24 to avoid a potentially safety critical error occurring, leaving 86 not intercepted. In addition, 35 actual medication errors were observed, with 22 being considered as preventable and 13 non-preventable. 72.7% of preventable medication errors lead to a serious negative outcome, with the remainder resulting in a significant negative outcome such as wrong medication dosage or wrong technique. Whilst this study highlights the prevalence of medication errors in ICU, it does not show factors that may contribute to such errors. Such a focus is outside the aims of the study, and the data collection method employed in this study limits what can be observed and logged accurately. There is also a potential for a Hawthorn effect, in that the true behaviour of those being observed may be influenced by the presence of an observer (McCambridge, Witton & Elbourn, 2014), therefore results may not be a true reflection of medications errors in this context.

In an American nationwide study of medication errors in the emergency department, Pham, Story, Hicks, Shore, Morlock, Cheung, Kelen & Pronovost (2011) reported that of 11,997 actual medication errors, 36% occurred during the administration stage, 29% at the prescribing stage, and 25% at the transcribing/documentation stage. Furthermore, of the reported errors (noting not all of these were classified as actual errors), 18% were typified as improper dose, and 11% were omission errors. This study analysed data obtained through Medmarx, and as previously indicated, contributing factors may be recorded but categorised at a high level. For example, the study identified that distractions contribute to 7.5% of medication errors. However, what constitutes a distraction is not clear, with the term being operationalised differently across the healthcare literature, with some defining them as interruptions and interruptions as distractions. as types of errors in one workplace may not be transferable to another (Guastello, 2014). Taken together, these studies show the need for additional work in this area to identify specific points to target interventions in order to minimise errors.

The magnitude of errors throughout the clinical medication process

The study of HF in a healthcare environment often puts the improvement of patient safety at the centre of workplace designs and interventions (Mao, Jia, Zhang, Zhao, Chen & Zhang, 2015). There are several HF approaches to improve patient safety, each of which has generated empirical investigation within more safety critical departments of the healthcare workplace (e.g., Intensive Care Unit/ICU, Emergency Department/ED, Accident and Emergency/A&E). These include the design, usability, and safe implementation of medical devices and health IT; physical ergonomics (e.g., manual handling, administering medication), cognitive performance (e.g., perception, attention, memory, problem solving); behavioural performance (e.g., decision-making, motivation); ability for the healthcare system to anticipate and adapt to changing contexts (system resilience); and human error (Carayon, Xie & Kianfar, 2013). All approaches are valuable in the understanding of a complex socio-technical system such as a healthcare work environment, however, human errors often receive substantial attention given the adverse consequences that may arise and potential impact patient safety.

Once a more holistic understanding of errors in the targeted system is developed, context specific interventions can be implemented to mitigate any negative effects such factors have within each layer of the systems defence. Such interventions may be targeted at a specific factor that has been identified as problematic, such as task interruptions (e.g., Raban & Westbrook, 2014; Relihan, O'brien, O'hara & Silke, 2010). These may include recommendations on the handling of interruptions, with special consideration given to the workplace setting, or, through the implementation of technological interventions that takes into consideration the necessity of some interruptions in safety critical healthcare settings (e.g., Sasangohar, Donmez, Easty & Trbovich, 2015). With the improvement of patient safety at the centre of healthcare initiatives, and errors within some healthcare contexts having possible safety critical effects, identifying error types, how they emerge, and factors that contribute to them has received substantial attention (e.g., Brady, Malone & Fleming, 2009; Keers, Williams, Cooke & Ashcroft, 2013; Makary & Daniel, 2016; Tang, Sheu, Yu, Wei & Chen, 2007).

Whilst many forms of errors within healthcare settings have been investigated, medication errors have received the most attention. It is suggested that medication errors are a frequently cited cause for unintentional incidents and accidents towards patients within a healthcare setting (Cloete, 2015); occurring throughout all stages of the medication process (e.g., ordering, prescribing, and administration; Roughead, Semple & Rosenfeld, 2013). Medication errors are often cited as having a collective detrimental effect on patients, the healthcare system, healthcare professionals, and economic impact (Schroers, 2018). A recent report by Elliott et al (2018) estimated that 237 million medications errors occur within the NHS England every year, with an estimated 712 deaths are the result of avoidable adverse drug reactions (ADRs). Furthermore, medication errors cost the NHS an estimate of £98.5 million per annum, and results in an additional 181,626 hospital bed-days.

It is recognised that medication administration is a high-risk task, in which the nurse is often the last clinical member to check the medication before it is administered to the patient (Davey, Britland & Naylor, 2008). The process of administration can be broken into three key stages - Pre-Administration Stage (preparation and checking of medication and patient details for whom the medication is to be administered too), Administration (administering medication to the patient), and post-Administration (monitoring and documentation of potential side effects, documentation signing of logged effects). Whilst all stages are important for safe medication administration, the Pre-Administration stage has been identified as being more at risk to interruptions than the other stages (Getnet & Bifftu, 2017; Sassaki, Cucolo & Perroca, 2019), however such errors are often only identified at the end of the administration process (Thomas, Donohue-Porter & Fishbein, 2017).

There are policies, procedures, and recommendations around safe medication administration to help prevent medication errors occurring. One such recommendation involves a series of checks the nurse performs on the patient and the medication prior to the medication being administered. Such checks have often been referred to as ‘The rights of safe medication administration’, however the amount and type of checks that are needed are often disputed (Elliott & Liu, 2010). The first proposed medication checking procedure referred to the ‘five rights’ of safe medication administration which represent ‘administering the right drug at the right time, in the right amount, in the right way, to the right patient’ (p 62. Kron, 1962). Following this recommendation, further literation’s included the ‘seven rights’ which adopts the same protocol with the addition of right reason/response and right documentation (Roth, Brewer & Wieck, 2015) while the ‘nine rights’ include steps for the right action and right form (Elliot & Liu, 2010). Table 2 presents examples of the potential adverse impact on the patient that may arise from failures in any of these pre-administration steps (Hughes & Blegen, 2008).

Table 2: Medication pre-administration steps recommended in the 9 'rights' to safely administering medication.

'Right' for safe medication administration	**Example of failed procedural step**
1. Right Drug	Wrong medication being administered to a patient.
2. Right Time	Administering medication at the wrong time, which have been before/after a specific dose range.
3. Right Dose	Administration of an inadequate dose of medication containing either too much or little of prescribed dose.
4. Right Route	Medication that has been administered through a route other than that suggested by the doctor.
5. Right Patient	Medication administered to patients that was not prescribed the medication.
6. Right Response	Failure to check earlier responses to medication, where the patient had a negative reaction or allergy.
7. Right Documentation	Signing the medication chart but forgetting to administer medication.
8. Right Action	Medication prescribed for the wrong reasons.
9. Right Form	Medication is in a liquid form for oral administration but is administered intravenously.

Despite the often-retrospective identification of medication administration errors, studies have provided insight as to where in the medication checking process these errors are likely to arise. For example, in a descriptive study Balas, Scott & Rogers (2006) explored the frequency and type of actual and near clinical errors as reported by 502 critical care nurses over a 28-day period. Medication errors were most frequently reported (N = 127), with the most reported type of medication error being medication administered at the wrong time (N = 48), an omitted medication dose (N = 28), or the wrong dose being given (N = 26). Furthermore, nurse narrative accounts often associated such errors to task interference (e.g., interruptions and/or distractions). Wondmieneh et al (2020) observed the level of adherence to the '*six rights*' of medication administration, and found that 15.1% of the time medication was given to the wrong patient; the wrong medication was administered 16.4% of the time; 23.1% of the time the wrong dose was given; medication was administered through the wrong route 14.2% of the time; 34.7% of medication being administered was so at the wrong time and 52% of medication administration events did not include the nurse documenting the necessary information.

Another observational study revealed from 855 medication errors, 40.3% where due to the wrong time of administration, 34.6% resulted in the wrong medication dose, and 20.9% were due to the wrong administration technique being used, whereby clinical task interruptions were reported to be a critical error producing factor (Ozkan, Kocaman, Ozturk & Seren, 2011). Clinical interruptions during the medication process may also vary in characteristics, such as frequency of occurrence (Craker, Myers, Eid, Parikh, McCarthy, Zink & Parikh, 2017), mode of communication (Biron, Loiselle & Lavoie-Tremblay, 2009) and the number of cognitive resources needed to successfully complete the primary task (Sasangohar, Donmez, Easty & Trbovich, 2017).

With the checking of medication being a crucial final stage before medication being administered, errors that arise during this final pre-administration process are difficult to observe. Given the high-risk nature of being interrupted during the medication checking, and this stage being the final stage for potential clinical error mitigation, it is important to understand the process in more detail and how various clinical task interruptions may impact pre-administration checks.

The contributing role of clinical task interruptions on medication errors

As highlighted above, errors within the medication process do not always arise in isolation, and there are often several contributing factors. In their review, Karavasiliadou and Athanasakis (2014), found several personal and system factors that have been reported throughout the literature as contributing factors to medication errors including increased workload (system/person), unreadable handwriting of medication orders (person), miscalculation of medication doses (person), and distractions and interruptions (system/person). Whilst this review shows that interruptions are a contributing factor to medication errors across healthcare settings internationally, none of the studies reviewed represent a UK sample. The results from past studies like this are informative in the design of more UK based studies that aim to investigate the contributing role of interruptions to error, but findings cannot be generalised to UK settings given the range of factors that may dictate the occurrence and handling of interruptions (e.g., level of staff training in interruption handling, hospital size, patient intake, staffing levels).

In an analysis of errors reported by surgeons that occur in the operating room, Gawande, Zinner, Studdert and Brennan (2003) found contributing system factors. Out of these incidents, 53% were due to lack of experience, 43% were associated with excessive workload, while interruptions/distractions contributed to 16%. The study used a critical incident technique (Flanagan, 1954) to gather more details in relation to incidents that had previously occurred and been reported. Whilst this technique was originally proposed to collect data as they occur through observations, it can be used retrospectively in interviews and questionnaires providing the events are recent (Urquhart, Light, Thomas, Barker, Yeoman, Cooper, Armstrong, Fenton, Lonsdale & Spink, 2003). This was not always the case in this study with some incidents originally reported longer than others, and the authors also report inconsistencies in recalling details for the older events, with participants at times underestimating the influence of interruptions. Adjusting this technique to recall critical events involving interruptions may provide better insights into their contributing role in errors.

Oshikoya, Oreagba, Ogunleye, Senbanjo, MacEbong & Olayemi (2013), reported risk factors to medication administration errors as perceived by nurses. Their survey results showed that nurses perceived increased workload as the most frequent risk factor (52%), followed by no double dosage checking (24%), similarity in drug labelling (20%), and interruptions (16%). Whilst nurses perceive interruptions and distractions to be a significant risk factor to medication errors, what is considered an interruption or distraction is not clear. Furthermore, such a result represents nurses across a variety of healthcare settings (e.g., ICU, outpatients, ED) across 5 hospitals in Nigeria. Therefore, not only may the nurse's belief on what constitutes an interruption or distraction may vary from setting to setting, but as previously mentioned each hospital setting varies in its characteristics. Whilst studying different settings within healthcare are key to fully understanding the role of interruptions, dissemination of findings need to represent each setting in relation to their unique characteristics.

The literature reviewed so far has provided insight into the study of human error, outlining some of the theoretical principles, and applied approaches in healthcare and safety critical healthcare settings. Through the understanding of how human errors appear, and the important contributing role of environmental and organisational factors, it opens the door to further understanding how researchers can approach such factors in innovative ways. Healthcare studies, including those in safety critical healthcare settings on human error, quite often identify task interruption as a common contributing factor to human error (e.g., Mayo & Duncan, 2004; Parry, Barriball & While 2015; Taxis & Barber, 2003; Unver, Tastan & Akbayrak, 2012). Such recognition of the role of interruption in human error has led to a surge of research on further understanding their effect within safety critical settings, although there is also a large body of research on task interruptions outside of workplace settings within carefully controlled experimental settings. The next section will first explore the theoretical approaches to task interruption, in order to provide insight into the cognitive mechanisms involved as well as the effects interruptions ‘should have’ on the individuals’ cognitive processes. It will then move onto research into varying characteristics of task interruptions and how they may be important to consider in safety critical healthcare settings.

A Memory for Goals Model of Task Interruptions

One of the leading models often used to explain the effects of task interruption is the Memory for Goals model (MfG: Altmann & Trafton, 2002, 2007), which draws from the literature on interference and decay, along with the highly influential Adaptive Control of Thought-Rational (ACT-R) cognitive architecture (Anderson, Bothell, Byrne, Douglass, Lebiere & Qin, 2004). MfG is a goal-activation based model, which posits that goal directed behaviour is decided by the most active goals in memory, with the frequency and/or the recency of a retrieved goal, or the relevance of the goals to the current task at hand enhancing the likelihood of successful goal activation (Hodgetts & Jones, 2007). The MfG model makes predictions about the suspension and resumption of task goals whilst also identifying the limitations of goal-directed behaviour, making this model theoretically plausible in exploring task interruptions.

Such limitations in goal directed behaviour were outlined by Altmann and Trafton (2002) in the first iteration of MfG (known then as the Goal Activation Model) and these included the level of interference (from other goals), strengthening (i.e., encoding) constraints, and priming (i.e., linking) constraints. Whilst the interference level is often as one process, it consists of two components: the type of interference and the interference threshold. The interference may be the interruption itself, where a primary task is suspended by a secondary task, and a situation occurs where management of multiple task goals in short-term memory is needed. These goals are in competition for a limited activation supply, and in addition may interfere with each other to gain control of behaviour. Therefore, the interference threshold may be referred to as the amount of activation the task goals receive during the interference. Goals that have activation levels below the threshold are less likely to be retrieved without e.g., linking to cues, while goals above the activation level tend to dominate and direct behaviour. Whilst attending to the interruption task, the activation level for the encoded suspended primary task goal(s) decays and that of the interruption task goal(s) increases.

The strengthening constraint implies that interruption task goals must take some priority in activation to ensure there is limited proactive interference from the suspended primary task, with such strengthening happening gradually, and in turn, creating a time cost in the encoding of new task goals. Consequently, because of the strength of activation of interruption task goals, the longer the interrupting task, the more time there is for primary task goals to decay and potentially become forgotten (Altmann & Trafton, 2002). Additionally, interrupting tasks with more goals to satisfy are more likely to create a greater amount of interference to the representations of suspended goals than interrupting tasks with fewer goals.

The activation level of the suspended goal(s) post-interruption dictates not only whether it is retrievable or not but also how long it will take to reactivate and retrieve the goal with the help of a previously linked priming cue (Cades, Boehm-Davis, Trafton & Monk, 2011). Linked to this, the priming constraint predicts the likelihood of successful retrieval of suspended task goals and resumption of primary task, with success rate dependent upon either rehearsal of suspended task goals or the use of associative cues which may be within the task environment or internally stored by the individual (Hodgetts, Vachon & Tremblay, 2014). Furthermore, the activation level of primary task goals may be strengthened prior to its suspension and before attending to an interruption during an interruption lag (time between the suspension of the primary task and interruption task that may be initiated by a signal, if one is available), using the same priming process of associative environmental cues (Trafton, Altmann, Brock & Mintz 2003). However, an interruption lag may not be as effective across all types of tasks (e.g., Cane, Cauchard & Weger, 2012).

According to the MfG model, there are three key factors that decide the disruptiveness of an interruption; its duration, the amount of rehearsal engaged in during the interruption lag (if there is one), and rehearsal opportunities afforded whilst performing the interruption task (Altmann & Trafton, 2002, 2007). With these factors, MfG allows interruption researchers to make predictions about the characteristics of an interruption such as interruption duration and complexity of interruption task. For example, longer interruptions tend to increase the likelihood of the activation level of a suspended task goal to decay, and more complex interruptions require greater allocation of task goals decreasing the opportunity of rehearsal for suspended task goals (Monk, Trafton & Boehm-Davis, 2008).

Such disruptive characteristics are often quantified by dependent measures such as the number and type of errors made in a task, and the time efficiency in completing the primary/interrupted task post-interruption (e.g., Altmann & Trafton, 2007; Bailey, Konstan & Carlis, 2001; Magrabi, Li, Dunn & Coiera, 2010; Morgan, Williams, Ings & Hughes, 2017). The time of resumption of the interrupted task may be a critical point in which errors and time-costs become clear, making it a common dependent measure often used in interruption studies (e.g., Altmann & Trafton, 2007; Iqbal & Bailey, 2005: Monk, Boehm-Davis & Trafton, 2004; Morgan, Patrick & Tiley, 2013). This is referred to as a resumption lag, which is operationalised as the time between the end of an interruption task and the first primary task related response (e.g., key press). Interruptions may also induce other effects on the individual such as evoking certain emotional responses (e.g., stress – Mark, Gudith, & Klocke, 2008; anxiety – Bailey, Konstan, & Carlis, 2001).

The procedural nature of the pre-medication administration checks allows for the examination of where in the procedural process errors are likely to occur. Task interruptions during procedural performance have been explored in-line with the MfG model. One experimental task that has been implemented is the UNRAVEL procedural memory task. Participants are required to learn the acronym UNRAVEL whereby each letter represents both a procedural step in a sequence and one of two possible responses that is decided by the participant based upon the stimuli presented to them (Example in: Altmann, Trafton & Hambrick, 2014). A key MfG assumption for performance on well learnt procedural tasks is that preparation for a procedural step occurs in semantic memory which then communicates with an execution process with the intention to complete the procedural step. If the communication between preparation and execution is disrupted by an interruption, errors in the procedure are more likely to arise (Trafton, Altmann & Ratwani, 2011).

Whilst the MfG model appears to be the most often cited theoretical model used to explain the effects of task interruption throughout the psychological literature, it has been the subject of some criticism. The MfG model (Altmann & Trafton, 2002) only makes direct predictions about the effects of the complexity of the primary task and duration of task interruption on goal directed behaviour, all of which is derived from the results of one quite artificial experimental task (Tower of Hanoi). Despite this, there has also been a healthy amount of theoretical and applied research using the MfG model to provide empirical insights into its predictions on complexity and duration, along with other interruption and primary task characteristics (many of which are explored in the next section). Even with such research, limited predictions in the MfG model would in turn limit the model's exploratory power, making it difficult for novel research findings to be interpreted in line with the MfG model (Borst, Taatgen & Rijn, 2015).

Furthermore, experimental studies have also identified that the likelihood of errors occurring may be influenced by several factors including task interruptions at various points of the current task at hand (e.g., Monk, Boehm-Davis & Trafton, 2002), similarity of the interruption to the current task at hand (e.g., Ledoux & Gordon, 2006; Lee & Duffy, 2015), and the duration of the interruption (e.g., Monk, Trafton & Boehm-Davis, 2008). Such research not only highlights the role interruptions play in contributing to errors in safety critical healthcare settings, but the need to fully understand their nature and characteristics to generate a more holistic understanding of their potential negative impact within such settings.

Characteristics of Task Interruptions

Complexity of Task Interruptions

Gillie and Broadbent (1989) were among the first to investigate the disruptive nature of task interrupting tasks that varied in terms of duration, similarity to the primary task, and complexity. Results indicated that the duration of an interruption alone cannot explain the disruptive nature of interruptions as markedly longer interrupting tasks were not more disruptive than shorter versions. However, interruption tasks with similar characteristics to the primary task, thought to increase the demands on memory resources (increased in complexity), were arguably central to the disruption caused. Despite such findings that the complexity of task interruptions may be dictated by the similarity of the primary and interruption task, such similarity effects may not always be present. Edwards & Gronlund (1998) found that when both the primary and interruption task share only some elements of the task that are similar, adverse effects on memory are not present, compared to when both tasks share all characteristics. Findings from both experiments begin to point to the importance of understanding the impact the content of both the primary and interruption task may have on cognitive processes, and how experimental controls over such content may dictate the impact of other subtle characteristics (e.g., number of steps needed to complete the task, complexity).

Interruption complexity was defined by Gillie & Broadbent (1989) as the amount of cognitive processing and memory storage the interruption task needed (with interruption similarity a factor adding to such memory constraints). However, as noted by Cades, Trafton, Boehm-Davis and Monk (2007) in reference to interruption complexity, the adverse effects do not seem to be as general, with other features relating to the difficulty of interrupted tasks (e.g., the amount of opportunity the task leaves for rehearsal of suspended task) also playing a key role. Support for this notion was found by Monk, Trafton and Boehm-Davis (2008) who reported that when an interruption task demand reduced available resources for rehearsal (increased in complexity), the time to resume the primary task after the interruption (resumption lag) increases. In addition, Hodgetts, and Jones (2005, 2006) reported a time cost in retrieving tasks goals whilst resuming a Tower of London (ToL) planning task; markedly so when the interrupting task increased in complexity and became more demanding.

There appears to be no consensus on how interruption complexity is defined throughout the interruption literature, and no clear distinction between interruption complexity and task difficulty. It's important to distinguish the two as any task may be perceived as difficult, particularly to a novice user of that task, whereas the complexity of completing the task may be dictated by its unique elements (e.g., multiple end points and paths to such points, uncertainty, conflicting interdependence) regardless of whether it is difficult or not (Campbell, 1988). Such factors may be particularly important when considering interruption complexity in a healthcare context, whereby interruptions may be perceived as complex due to their safety critical nature and time constraints (Thomas, Donohue-Porter & Stein, 2017). Furthermore, interruption complexity may not be the only important characteristic to consider in theory or practice. Cades, Werner, Trafton, Boehm-Davis and Monk (2008) reported a small effect size of interruption complexity, which shows that such a characteristic has minimal magnitude, and that complexity alone cannot explain fully what increases/decreases susceptibility to profound effects of interruptions.

However, this may not always be the case when exploring interruption complexity in healthcare settings. Whilst complexity to some extent may be a subjective concept to many that is often dependent upon various characteristics, it may also vary across individuals and workplace settings. Relating to this, cognitive workload (which is often used to operationalise complexity) may also be defined and measured differently from study to study. For example, Tissot et al (2003) defined workload as the number of patients per nurse (e.g., more patients higher workload) when exploring risk factors to medication administration error. From such operationalisation of workload, the authors were able to observe nurses' routine work and found workload to be a significant risk factor to medication administration errors.

However, such a definition is constrained to assume that whilst the number of patients per nurse may vary, the tasks in which the nurse performs with the patient still is consistent. It is also important to consider the subjective workload of the healthcare practitioner and how clinical task interruptions may affect such perceptions of workload. Weigl, Muller, Vincent, Angerer & Sevdalis (2012) explored the relationship between clinical workflow task interruptions and perceived workload in doctors through observations and a subjective workload measure - the NASA Task Load Index (Hart & Staveland, 1988) - which was completed twice by doctors throughout the shift. It was found that interruptions were significantly related to doctor's workload when seniority of the doctor and time of day were controlled for, indicating that when interrupted, workload ratings increased with interruptions accounting for 5% variance in the workload ratings.

Frequency of Task Interruptions

Given the interrupt driven nature of a healthcare setting, which is at times reliant upon interruptions for successful communication between multiple interdisciplinary work systems to ensure patient safety is maintained, it is no surprise that they are often characterised as frequent. Frequency of task interruptions is a characteristic that has also been explored within the psychological literature. Speier, Valacich and Vessey (1999) explored low (4 interruptions) and high (12 interruptions) frequency of task interruptions on a decision-making task. Such interruptions occurred between 7 and 15 seconds within the decision-making task, whereby higher frequency of interruptions showed performance deficits in decision accuracy and increased time to make a decision. Whilst this study was particularly focused on decision making performance, Monk (2004) took more of a focus on how interruption frequency may impact primary task resumption and resumption error (errors that occur immediately after the interruption). Using a Video Cassette Recorder (VCR) programming primary task and pursuit tracking interruption task, participants were interrupted every 30 seconds for infrequent interruptions and every 10 seconds for frequent. Results showed that frequent interruptions surprisingly improved primary task resumption after an interruption and resumption error rates decreased.

Such results suggest that individuals may adapt to the quick pace of the interruption task. However, if this was always the case, interruptions in dynamic healthcare settings with highly trained healthcare professionals would have less of a profound effect than is often reported. Rather, such results may be better explained by the time constraint placed on the interruption task (participants only had 5 seconds to complete the interruption task before immediately switching back to the primary task), therefore it's possible that task resumption may become predictable. Such constraints do not best represent interruptions that occur within healthcare contexts, as the interruption at times may take equal priority to that of the primary task and often being significantly longer before they resume back to the original task at hand (e.g., Brixey et al, 2008; Westbrook, Ampt, Kearney & Rob, 2008).

Interruption Source

The source of a task interruption refers to the source in which the interruption is initiated. That is, interruptions can be initiated through numerous sensory modalities including face-to-face, auditory (e.g., telephone) or electronically (e.g., email). Given the complex socio-technical environment in which healthcare professionals work within, it is no surprise that interruptions can be initiated through various modalities. Much of the past research on interruption source, particularly within a healthcare context, has only been explored in terms of frequency of occurrence (e.g., McGillis-Hall et al, 2010; Schutijser et al, 2019). There is limited research exploring varied effects such interruption modalities may have on individual performance. Understanding such effects may inform more targeted interventions that best fits the appropriate prioritisation on source in terms on healthcare norms (e.g., prioritising a beeper over a telephone as the beeper is to be used only in emergencies; Wajcman & Rose, 2011).

In a descriptive study exploring nurses' responses to interruptions during a medication task and the contextual factors around them, Reed, Minnick and Dietrich l (2018) reported the following. Nurse responded to 94.6% of interruptions whereby 47.9% required a switch in task. 56.8% of interruptions were initiated by face-to-face, 10.8% through personal computer device, and 3.6% by telephone. The main reasons for these interruptions included a question being asked to the nurse administering (43.8%) and to provide a notification (39.6%). Such notifications were recorded as work-related notifications. Furthermore, descriptive observations suggest that nurses were more likely to switch task when interrupted by telephone (100%) compared to personal computer device (26.7%) and face-to-face (43%). Such results indicate that telephone-initiated interruptions may be more disruptive in that they are more likely to initiate a break in the task at hand.

More recently, Wang et al (2021) reported that of all the environmental factors, non-work-related telephone calls accounted for 16.46% of interruptions to nurses' work, and Doctors asking for an update on a patient's condition account for 17.05% of interruptions. Similarly, Schneider et al (2021) found that interruptions from colleagues of different professions occurred on average 3.15 per hour, while other interruptions which includes telephones, occurred on average 1.77 per hour. Vaisman & Wu (2017) considered the introduction of technology to assist healthcare workflow. The authors explored work smartphone interruptions and found that across two observation sites the daily team average for smartphone interruptions ranged from 42.4 – 51.4. Of those between 6 – 15.8 were email interruptions and between 22.4 – 27.1 were telephone calls.

Whilst it is evident that the source of clinical task interruptions can be diverse and frequently occurring, a better understanding of any potential direct effects of common modes of interference is needed. This may particularly relevant when there are more safety critical tasks being completed, such as the administration of medication. This may better facilitate and better direct proposed interventions in specific clinical tasks (e.g., if it is found emails are more problematic during the medication process, could user design principles help minimise emails at these critical times?). Furthermore, experimental studies have shown that task similarity between the primary task at hand and the interruption task can have a negative impact on primary task performance (e.g., Lee & Duffy, 2012). Often, such findings are based on similarities between the task operations as opposed to the source in which they are being presented. However, if the modalities share similarities (e.g., both have been visual or auditory), it may be possible that confusion between similar source tasks are more prominent than task modalities that are unsimilar (Wickens, 1992).

Emotive Characteristics of Task Interruptions

Much of the literature exploring the impacts of various characteristics of task interruptions often focus on the cognitive mediators (e.g., increased complexity, source in which interruption is initiated). There are practical benefits to understanding the role of emotions on task interruptions and cognitive performance, both of which are likely to occur on a day-to-day basis in high emotional work environments such as healthcare.

It has been suggested that emotions work interdependently with cognitions to control and mediate cognitive processes including working memory and attention (Storbeck and Clore. 2007). Emotional stimuli are said to have an impact on cognitive performance as it can draw attention away from a primary task, leaving a limited number of resources for task completion (Verbruggen and De Houwer. 2007). Emotional stimuli are often measured in two ways, the positive or negative affective nature of the emotive stimuli (valence), and the extent of excitement caused by the emotive stimuli (arousal) (Labar and Cabeza. 2006).

Emotional information is more likely to be remembered than neutral information (Kensinger and Corkin. 2004). For example, Hamann et al (1999) found that words and images of a pleasant or aversive nature were remembered more than neutral information. Through a series of experiments Kensinger and Corkin (2003) reported that individuals were more likely to remember words with a negative valence compared to neutral words. They suggest that this was due to the elaboration of negative words during the encoding of information, which enhanced the likelihood of them being recalled. However, this does not account for words with a positive valence. Chan and Singhal (2013) investigated the effects of emotional distractions of billboards containing either neutral, positive, or negative words on driver performance. Results indicated that the distractions of positive and negative emotional stimuli adversely affect driving ability. Also, a memory recall test revealed that participants were more likely to remember positive and negative words as opposed to natural words, but also more negative words as opposed to positive words.

There are associated emotional costs in addition to the well-cited cognitive cost of interruption on subsequent performance (Mark et al., 2008; Adamczyk & Bailey, 2004; Brumby et al., 2014). There are conflicting findings of the effects of the emotive nature of task interruptions on performance (Kensinger & Corkin, 2003; Levens & Phelps, 2008; Lindstrom & Bohlin, 2010). A study by Morgan and colleagues (2015; 2017) investigated the effects of interruptions with associated valence on subsequent performance in a memory recall word task. To do so effectively, they also controlled for levels of arousal as valences often differ in this regard and are hard to disentangle (Kensinger, 2004). Throughout the task, some trials were interrupted with images of scenes with varying levels of valence (e.g., negative and positive) and strength (e.g., moderate and strong). Findings indicated greater impaired memory recall was associated with negative valence trials and at points which had longer words to recall (i.e., higher working-memory load). Whereas positive valence interruptions were less disruptive.

Notably, in Morgan and colleagues' study (2017) the interruptions depicting emotional scenes were obscure compared to the primary task. Interruptions within natural working environments may be unpredictable, but they are often task-relevant also. Other findings indicate that the dissimilarity of interruption content could lead to exacerbating interruption effect (Speier et al., 1999) and that both negative and positive emotion has a effective and increasing effect on performance if the task is emotionally relevant (Anderson & Phelps, 2001; Vuilleumier, 2005).

Pessoa (2009) proposed a theoretical framework for emotion-executive function and interactions from cognitive operations such as working memory updating and inhibition. The theory assumes that there are limited cognitive resources between different representations on both perceptual and executive levels (Miller & Cohen, 2001) and both executive control and emotion can influence this competition. This moderation of cognitive resources from the emotion-executive function suggests that representations (e.g., of a stimulus or a task) that have affective characteristics and are relevant for task goals are more likely to influence behaviour than task-irrelevant or non-emotional representations.

Urgency of Task Interruptions

It is possible, particularly within a healthcare context, that individuals are faced with an interruption that is characterised as urgent in that it takes priority and requires a short set of time to complete the task. Such time constraints, and potential threat of failure to complete the task due to its urgent nature could place additional costs upon an individual in terms of both anxiety and stress (Hopkinson & Jennings, 2013). Whilst there are benefits to attending to a task interruption that is urgent (e.g., improvement of patient care), such interruptions may not always be considered urgent with frequent non-urgent task interruptions in healthcare being reported as safety concern within the literature. For example, Ly et al (2013) reported that of all interruptions that were initiated through a healthcare communication pager, only 27% were considered as urgent whilst 58% were non-urgent but still required attention to be moved from the current task at hand. Whilst this study highlights those non-urgent interruptions are more prominent, it is not clear what constitutes the urgency. For example, in a recent study, Armendariz et al (2021) characterised clinical interruption urgency based upon the time in which the interruption needs to be responded by. These included: Routine (Not requiring immediate attention within the hour), Urgent (Attention needed within the hour), Emergent (Immediate attention needed) and Personal (Non-work-related interruptions). Based upon this characterisation of urgency, 80% of task interruptions were found to be routine (not urgent).

The cognitive demands of nurses can be viewed as cognitive stacking whereby nurses are frequently expected to evaluate numerous tasks and priorities to ensure sufficient patient care is achieved (Potter et al, 2005). This places additional cognitive load on nurses, and such continuous shifts may result in a loss of attention and contribute to errors (Thomas, Donohue-Porter & Fishbein, 2017). Furthermore, frequent shifts in attention to tasks that may be perceived as more urgent, may cause sudden pauses to the current task at hand and limit successful resumption due to little time to consider behavioural strategies in aiding such resumption. Whilst this is positive behaviours from a nurse as a more urgent task has been prioritised, the suspended task is still at risk of error with potential negative implications towards patient safety.

There is scarce research looking at the impact of urgent interruptions on medication errors. By not acknowledging this, it may limit the impact of interventions (particularly those that block all forms of interruptions e.g., interruption free zones) due to restraints placed on professional decision making. Such restraints could potentially have secondary effects in that the primary task is not interrupted but the more urgent task that required assistant was impacted. It's important to understand the impact of healthcare specific variables such as urgency, it could better inform more flexible interventions that doesn't place restrictions to the multi-facet nature of task interruptions.

Urgency of an interruption may be characterised in a healthcare context as a critical task that is limited by time constraints. That is, healthcare professionals only have a set amount of time to complete the secondary task, and once that time ends, there is forced resumption to the primary task, regardless of successful completion of the secondary task. In this case, participants might be given insufficient time to finish the secondary task before resumption to the primary task and may experience failure-stress resulting from unsuccessful secondary task completion. Research has demonstrated the detrimental effects of failure-stress upon task performance, such that failure-stress reduces ability to recall items and increases error rates in recall of nonsense syllables.

There is little research on the influence of time constraints within a secondary task upon primary task performance, with research primarily considering performance of a primary task in isolation. Benbasat and Dexter (1985) found that participants' performance in a decision-making task deteriorated when time was restricted; this was attributed to greater difficulty finding and processing information under time constraints. Additionally, Jameson, Schäfer, Weis, Berthold, & Weyrath, (1998) found that increased time pressure negatively affected both the time spent trying to understand the task and the likelihood of correct completion. Altmann, Trafton and Hambrick (2014) found momentary (i.e., very short) interruptions can almost double the rate of sequence errors, and further found that various interruption durations adversely impact sequence errors differently dependent upon the offset within the task they occur (Altmann, Trafton & Hambrick, 2017). Such studies demonstrate that restricting available time induces a performance constraint.

Methods to alleviate the negative effects of task interruptions.

Research has shown that the use of an interruption lag may be a useful intervention to strengthen the encoding of primary task goals prior to an interruption (e.g., Bailey & Iqbal, 2008; Hodgetts & Jones, 2003; Trafton, Altmann, Brock & Mintz, 2003). However, some settings, such as safety critical healthcare settings, may not provide an opportunity for strengthen encoding task codes, as interruptions may need immediate attending to due to the emergency nature of the interruption (e.g., patient admitted for emergency treatment; Palanque, Winckler & Martinie, 2011).

Theoretical driven studies on task interruptions often place a lot of emphasis on the use of a resumption lag as a valid measure and insight into interruption effects (e.g., Altmann & Trafton, 2007). However, such a measure does not always dictate whether an error is likely to occur, as some individuals may take longer to resume a task post-interruption, but in turn make less mistakes (e.g., Brumby, Cox, Back & Gould, 2013).

Furthermore, despite an interruption lag being present, some may not use that opportunity to actively encode task goals. For example, Morgan, Patrick & Tiley (2013) manipulated the information access cost of uncovering information relevant to the task at hand to encourage a more memory-based strategy, which in turn improved the effectiveness of an interruption lag. That is, participants who experienced high access cost conditions (task goals were revealed after a mouse cursor was placed over the window and a 2.5 second delay) could successfully complete more task goals post-interruption with an interruption lag than those without an interruption lag and with less information access costs (e.g., task goals always present). Whilst many positive effects of such interventions have been reported, little has explored such impacts within a healthcare context.

Research which has looked at mitigating the negative effects of interruptions during medication administration have mainly focused on trying to minimise the number of interruptions made. When looking at different interventions, including a 'Verification Booth' – a physically distinct quiet space to perform medication verifications, and a 'No Interruption Zone' with a motion-activated 'busy' indicator, Prakash, and colleagues (2014) found that interventions successfully reduced errors of commission, but had mixed results concerning errors of detection. They concluded that people-dependent interventions alone are not enough to successfully reduce routine, predictable errors of detection. It was suggested that interventions that are more automated and rely less on human memory and vigilance would be beneficial (Prakash, Koczmara, Savage, Trip, Stewart, McCurdie, Cafazzo & Trbovich, 2014).

Using temporary interruption free zones that encourage focus on medication administration can significantly reduce medication errors (Pape et al., 2005). However, it has been suggested that interruption free zones may impede on a healthcare professionals perceived capabilities, due to such interventions assuming that all medical tasks are equal and not allowing for professionals to select and engage in important interruptions (as some interruptions may be), which in turn may result in problems and reduce the quality of patient care (Colligan & Bass, 2012).

Drug round tabards have been explored as method to minimise interruptions during the administration of medication. Tabards are highly visible vest that indicate a nurse may be undergoing a medication round, and therefore should not be disturbed. In a pre and post implementation study, Verweij et al (2014) found that interruptions during medication administration were reduced by 75% post implementation of tabards. Contrary to this finding, research has suggested the evidence for its effectives is limited (e.g., Raban & Westbrook, 2013). This may be due to differentiating findings being reported whereby only certain interruptions are mitigated while others are not (Tomietto et al, 2012). Furthermore, the perception of tabards is often negative which may limit its use by nurses (Hayes eta al, 2014; Verweij et al, 2014).

It has also been suggested that employing a combination of designs and methods that mitigate the profound effects of interruptions and distraction may further significantly decrease medication errors. For example, Freeman et al. (2013) found that interventions including interruption free zones, minimisation of pages and calls at administration times, and education and training on interruption strategies, significantly decreased the frequency of interruptions along with the number of medication administration errors caused due to experiencing them. Similar results were also reported by Relihan et al (2010) which further supports the use of multifactorial interventions in reducing interruptions and distractions during medication administration.

Behavioural approaches to mitigating the negative effects of interruptions often do not try and isolate tasks and attempt to stop all interruptions. Rather, they generally acknowledge that not all interruptions may be bad, and some may require attention, therefore understanding effective behavioural strategies may be better suited in a healthcare context. Colligan & Bass

(2016) undertook interviews to understand interruption management strategies in paediatric medication administration. From this it was identified that nurses used four different behavioural strategies to manage the interruptions (Table 3).

Table 3: Interruption behavioural strategies most often used by healthcare professionals.

Interruption Behavioural Strategy	Example
Blocking	Not responding to an interruption
Multitasking	Simultaneously continue to work on the primary task whilst also working on the interruption task.
Engaging	Nurses actively stops the primary task and engages with the interruption task.
Mediating	Nurses evaluates the interruption and before attending performs actions to support resumption back to the primary task.

Such behavioural strategies have been validated to apply within different healthcare contexts (Johnson et al, 2018; Johnson et al, 2019; Karavasiliadou & Athanasakis, 2014), however each strategy has its limitations. Blocking an interruption may be detrimental if it is done so without considering the nature of the interruption (e.g., if it is more urgent than the current ask at hand). This would suggest that a better strategy would be to mediate the interruption, however mediation can only occur within primary tasks that allow support and certain stages of the medication process may not cater for such mediation. Whilst multitasking is a key characteristic for the healthcare context, it may also increase the likelihood of an error occurring on either or both task (e.g., Monsel, 2003; Speier, Valacich & Vessey, 1999). Finally, engaging with the interruption task without mediation may increase the risk of either not returning to the primary task, or increase the rate of errors.

There have also been attempts at utilising technology to mitigate errors through the proposition of an improvement of the medication process, exclusion of situational risk factors, and error interception (Moyen, Camire & Stelfox, 2008). Such strategies include the introduction of Computerised Physician Order Entry (CPOE) and Clinical Decision Support Systems (CDSS), which attempt to reduce errors within the medication ordering process by reducing extensive prescription errors as well as aiding successful transcription of medication orders (Frisse et al., 2015). Such systems constrain decisions based upon strict procedures (rule-based errors), provide alerts when there is a possibility of re-administrating a drug due to attentional slips or memory lapses (skill-based errors), and provide professionals with mathematical dosages for drugs along with details on the effects of drug interactions (knowledge-based errors; Fernandez & Gillis-Ring, 2003). In addition, other technological interventions have also been shown to reduce errors within stages of the medication process which include Automated Dispensing Cabinets (ADC; Accordino, 2009), and bar-coding systems (Karsh et al., 2011).

Technological interventions thus seem to be important to reducing human medication errors, yet organisations are reluctant to implementing such designs, which may be attributed to costs as well as the trade-off between cost and exceeding the probability of error reduction/prevention (Brady, Malone, & Fleming, 2009; Charles, Willis, & Coustasse, 2014). Furthermore, technological interventions that reduce certain errors may enforce the creation of other errors. Wickens (1992) referred to these in his error classification theory as mode errors, which arise due to inadequate system designs that tolerate mode confusion (action between operator and system does not match) resulting in the incorrect procedure being carried out (Stanton, 2001). Furthermore, studies have indicated that interruptions and distractions during the use of CPOE systems may create errors during the processing of information and/or communication between the human and computer (Ash, Berg, & Coiera, 2004). For example, Collins et al., (2007) found that a distraction or interruption occurred every five mins during the use of CPOE, which in turn resulted in order entry errors.

Given the increase in the implementation of technology to aid healthcare professionals, there may be opportunities in the design of such technologies to unobtrusively encourage effective cognitive strategies that would aid successful handling of task interruptions. The Theory of Soft Constraints (ToSC) focuses on interactive behaviour and proposes that low-level task strategies made up of perceptual, cognitive, and motor elements are selected to minimise time costs. It was proposed that tasks are composed of hard constraints which are fixed and determine what interactive behaviour is or isn't possible, and soft constraints that are determined by strategy selection. While people have no control over the hard constraints of a task, they do have control over the soft constraints by choosing how to tackle the task through the nature of the strategy to be employed (Gray & Fu, 2004; Gray, Sims, Fu & Schoelles, 2006).

According to ToSC, cognitive strategy is flexible and will adapt realistically to small changes at the millisecond level in how information is accessed within the task environment (Gray & Boehm-Davies, 2000). When information is easily accessible within the task environment, people will implement a strategy that relies on the environment as an external memory resource, reducing demands on internal memory. If there is a small-time delay associated with accessing the information, people will adapt and switch to a more internalized strategy that entails encoding the information in memory, which minimises the need to access information and pay the time cost (Gray et al., 2006). Therefore, manipulating the cost of accessing information can be exploited to influence the extent to which a memory-based strategy is selected.

Information accessibility is defined by how easy it is to access the information required to complete a task. This can be manipulated by having the information readily available to the participant (e.g., on the computer screen next to the task) or adding some delay to viewing the information (e.g., having to move the mouse cursor to access it). Information access cost (IAC) refers to the time, physical and cognitive effort associated with accessing information (Morgan, Patrick and Tiley, 2013). Considerable empirical evidence now exists supporting the prediction of the Theory of Soft Constraints that increasing IAC will encourage a more intensive memory-based approach. Simply obstructing information, sometimes with an additional time cost to access it, can make participants shift to a more intensive memory-based planning strategy (Gray & Fu, 2004; Gray et al., 2006).

This has been found to improve memory recall (Morgan et al., 2009; Waldron, Patrick & Duggan, 2011), and problem-solving efficiency (Morgan & Patrick, 2013). Morgan and Patrick (2013) examined whether the manipulation of goal-state access cost can mitigate the negative effects of interruption during problem solving. As the MfG model states: goals committed to memory are at risk of being forgotten when suspended. Expectation based on the model was that a person's goals or sub-goals would be strengthened through the increased encoding provoked by the extra memory-based planning induced in the high IAC condition. This, in turn, was expected to mitigate the effects of interruption. It was found that participants engaged in more memory-based planning, enabling them to better resume problem-solving post-interruption and maintain their problem-solving efficiency after interruption with fewer moves to solve the Tower of Hanoi (Morgan & Patrick, 2013). It could be that an 'increase' rather than 'decrease' access costs to non-urgent interrupting and distracting communicative channels such as email and notifications to encourage less overuse and misuse. For example, Gould et al. (2016) found that brief task lockouts (< 5-s) encourage checking behaviours whereas longer lockouts promote switching to more productive tasks.

When looking at the effects of training on task performance with regards to IAC, it was found that training in one access cost condition (e.g. high) influenced the degree of memory-based strategy adopted subsequently when performing the task with a different constraint, which would normally be associated with a lower degree of memory-based strategy (e.g. medium IAC) (Patrick, Morgan, Smy, Tiley, Seeby, Patrick & Evans, 2015). It was also found that adding another 2.5 second time cost on one instance alone did not have a discernible effect on level of strategy adopted but paying this cost on two or three consecutive viewings of the target pattern did have an effect, and an even greater memory-based strategy was adopted (Patrick et al., 2015). These provide further evidence in support of the ToSC. However, these experiments lack ecological validity, and more research into the effects of IAC needs to be done looking at real world contexts.

Summary

It is evident from the literature reviewed, that the study of task interruptions and factors that mediate its effects is widely explored across various domains. When comparing the psychological and healthcare literature, both generally adopt different approaches to explore and report the impact of task interruptions on performance. Psychological studies often adopt a controlled experimental method to explain non-observable characteristics of task interruptions and the underlying effects these may have on human cognition and performance. However, healthcare studies usually take a more qualitative methodological standpoint, often exploring the observable characteristics of clinical task interruptions within the healthcare workplace to provide insight into the possible causal relationship they may have with clinical errors.

While both approaches offer valuable insights into the role of task interruptions and capture the complex nature of trying to understand interruptions in complex working environments such as healthcare, there appears to be a lack of a direct link between theoretically informed findings on the characteristics of clinical task interruptions that could underlie their disruptiveness. One possible contribution to the lack of direct links could be in the differentiation in how studies operationalise a task interruption, making it difficult to draw consistent conclusions. This is particularly evident within the healthcare literature, whereby distractions are often defined as interruptions and vice versa. Furthermore, the focus on types of errors that may occur because of an interruption may vary depending on the context and may not be completely transferable/generalisable to other contexts.

Some experimental studies have attempted to generalise their findings to healthcare settings, even more so when the focus of research is on tasks that best represent well-learnt skills and procedures assumed to mimic tasks/subtasks in some settings. While such tasks may represent elements (e.g., a sequential procedure) of some clinical tasks that follow similar processes (e.g., medication administration), both the primary task and interruption task in many of these studies lack domain-specific content that would better capture the varying properties such clinical tasks may have (McCurdie, Sanderson & Aitken, 2017). While some clinical tasks are procedural in nature, the nature of the steps required are often different (in terms of healthcare characteristics such as emotivity and urgency) compared to the laboratory-based tasks used. Likewise, task interruptions during clinical tasks may also vary in similar characteristics, whereby interruptions may vary significantly by their frequency, mode of communication and the number of cognitive resources needed to successfully complete. Bridging this gap with theoretically informed studies using tasks (primary and interrupting) with a high level of ecological validity is thus a very important step for both fields. Only then, should we consider possible methods to alleviate disruptive effects. Through this approach, tasks can be design around procedures that are difficult to fully explore through qualitative methods, such as the checking of medication. Whilst there is extensive literature exploring the contributing role of task interruptions on medication error, these are mainly done retrospectively, after the error has occurred. With medication checking being the final stage for potential clinical error mitigation, it is important to understand the process in more detail and how various clinical task interruptions may impact pre-administration checks.

Healthcare interventions that are aimed at reducing clinical task interruptions during the medication administration process have been shown to have limited effectiveness when implemented. There have also been attempts at utilising technology to mitigate errors caused by interruptions through the proposition of an improvement of the medication process, exclusion of situational risk factors, and error interception (Moyen, Camire & Stelfox, 2008). Error mitigation using technology that improves the medication process, whilst at times is successful in limiting some human medication errors, may enforce the creation of other errors (Wickens, 1992). Furthermore, such interventions are usually designed to reduce cognitive load of the human operator during clinical tasks (and thus reduce the potential for error), but often designs do not account for situational factors such as task interruptions during the use of these technological interventions (Ash, Berg & Coiera, 2004; Collins et al, 2006). Whilst it may seem that healthcare technology may be a possible solution for error mitigation in the face of task interruptions, more research is needed in understanding the characteristics of healthcare task interruptions that may potentially increase or decline the likelihood of errors occurring. Such factors include understanding how healthcare professionals' cognition is affected by clinical task interruptions, which may enhance and/or extend the explanatory power of current interruption theories and models, and in turn potentially inform more robust, cost-effective technological designs, that offer flexible ways to effectively handle such interruptions within dynamic safety critical work settings.

Prior to undertaking experimental exploration, a questionnaire study was used to better understand the nature of task interruptions amongst healthcare professionals within safety critical settings. Findings from this study partially informed the experimental design alongside the extended literature reviewed. The experiments propose the use of a theoretically informed experimental design, employing a procedural memory drug administration primary task similar to a task used in healthcare settings.

Furthermore, the parameters of the task will be explored through interruption manipulations that mimic those that healthcare professionals are likely to experience on a regular basis including interruption complexity, frequency, and mode of communication. Traditional experimental tasks used to explore task interruptions have provided useful information in understanding interruption effects, but the translation to clinical practice is still unclear. The use of more realistic yet controllable tasks will enhance the potential application of the findings, inform current theories and models of task interruptions in an applied context, and lead the way for better informed interventions to mitigate the profound effects such clinical task interruptions have.

Chapter 3: Exploratory Questionnaire Study: What are the characteristics and perceived impact of task interruptions by healthcare professionals in a UK hospital setting?

Introduction

Past research shows that working memory performance is often disrupted by external interference factors, such as interruptions and distractions, which can have a negative impact on human performance (Clapp, Rubens & Gazzaley, 2009). Such negative impacts are particularly problematic within a healthcare setting, whereby patient safety is at risk. Interruptions are conceptualised differently to distractions throughout the psychological literature, in that interruptions often refer to the reallocation of cognitive resources to a secondary stimulus, which requires the individual to shift their attention away from the primary task at hand (Altmann & Trafton, 2002). Distractions on the other hand, tend to refer to irrelevant background stimuli that are often intended to be ignored (Lavie, 2010). The key difference is that the primary task is still attended to in a distraction situation, although its performance is likely to be impaired due to the presence and characteristics of the distraction.

Psychological studies have found differential effects of both interruptions and distractions. Whilst the literature review has highlighted the effects of task interruptions (both theoretically and within a healthcare context), the distinction between interruptions and distractions needs to be further explored using empirical research methods. This will provide further understanding of, and justification for, the exploration of interruptions and distractions within the exploratory study. Clarifying such differences will aid perceptions of task interruptions and distractions, specifically within a work-based setting which will help guide further research.

The effects of distractions are often explored through selective attention research, as opposed to interruption research which derives from memory models, with a large, applied focus in driving research (e.g., Lansdown, Stephens & Walker, 2015; Young, Regan & Hammer, 2007), educational research (e.g., Rabiner, Murray, Schmid & Malone, 2004), and industrial workplace settings (e.g., Wallace & Vodanovich, 2003). Quite often two modalities of distractions explored: auditory distractions and visual distractions. Studies on auditory distractions have revealed their disruptive nature on several cognitive processes including short-term memory (e.g., Banbury, Macken, Tremblay & Jones, 2001), working memory performance (e.g., Chein & Fiez, 2010), and the ability to serially recall and/or immediately free recall task relevant items (e.g., Marsh, Hughes & Jones, 2009).

Likewise, visual distractions have also been found to negatively impact the quality of eye-witness testimonies (e.g., Perfect, Andrade & Syrett, 2011), and impair memory retrieval (e.g., Mastroberardino & Vredeveldt, 2014; Wais & Gazzaley, 2014). Such effects of distractions may be influenced by several characteristics including varying sound sequences (e.g., changing-state effect; Jones & Macken, 1993), the level of attentional capture (e.g., the deviation effects; Hughes, Vachon & Jones, 2005), age (e.g., Bell, Buchner & Mund, 2008) and working memory capacity (e.g., Sorqvist, 2010). Some authors have explicitly highlighted the differences between interruption and distraction paradigms, in that distractions require non-task information that is irrelevant to the current task at hand to be ignored as much as possible. In comparison, interruptions require the secondary task to be attended and at times responded to thus requiring a level of attentional resourcing to two tasks (Craik, 2014; Wais & Gazzaley, 2014).

The effects of distractions have been investigated within safety critical healthcare settings, with the focus often being within the operating room. For example, in a prospective cross-sectional observational study, Wheelock, Suliman, Wharton, Babu, Hull, Vincent, Sevdalis & Arors (2015) found that distractions (visual and auditory) in an UK operating room were associated with impaired team performance. More specifically, such impairments included deficits in coordination and leadership effectiveness and were often associated with irrelevant conversations by surgical team members. Furthermore, equipment related distraction was associated with higher levels of stress and lower team working amongst nurses, while acoustic distractions (including pagers, phones, and radios) were associated with higher stress in surgeons and increased workload in anaesthesiologists.

In another study, Campbell, Arfanis, & Smith (2012) observed anaesthetists in a variety of surgical settings in the UK. 424 distractions occurred throughout each stage of the anaesthetic process: within the anaesthetic room (total =138/0.29 per min), between leaving the anaesthetic room and first skin incision (total = 72/0.33 per min), intraoperatively (total = 153/0.15 per min), and during emergence (total = 61/0.5 per min). Of the distractions observed, approximately 22% were perceived to have a profound effect on patient care which included: repeated attempts of the same procedure, delays in procedures, prevention of smooth induction of anaesthesia, and deterioration of physiological variables. Jothiraj, Howland-Harris, Evley &

Moppett (2013) observed the source, frequency, and urgency of distractions experienced by UK anaesthetists. The authors reported that the anaesthetist and circulating nurses were the most frequent distraction, with movements and communication being the most common source reported. Of the communication distractions that were initiated by the anaesthetist, 55% were irrelevant to the case.

Despite some informative findings from existing studies, there are numerous limitations regarding the defining and operationalisation of interruptions and distractions throughout the healthcare literature. It has been suggested that regardless of the definitions used to define an interruption and/or distraction, the issue remains that a shift in focussed attention increases the likelihood of an error occurring (Rivera-Rodriguez & Karsh, 2010). Numerous definitions of interruptions have been provided throughout the healthcare literature some of which do not imply shifts in attention. Furthermore, studies that take a direct focus on distractions within safety critical healthcare settings (e.g., Jothiraj, Howland-Harris, Evley & Moppett, 2013; Wheelock, Suliman, Wharton, Babu, Hull, Vincent, Sevdalis & Arora, 2015) often utilise a standardised observation log sheet that allows for the observers to rate the severity of the distraction.

Such a tool was developed by Healey, Sevdalis & Vincent (2006) to measure interruptions and distractions in the operating theatre. Despite the authors attempts to distinguish between an interruption and distraction, the two concepts are often used interchangeably throughout the predefined categorisation of interferences. For example, scale points 4-6 narrate the individual being distracted by an event, with scale point 5 and 6 referring to pausing the current task and attending the distraction respectively. Such defining of scale points is more in line with psychological definitions of interruptions (e.g., Altmann & Trafton, 2002), and further adds to the range of definitions identified in Table 4 provided throughout the healthcare literature. With interruptions at times being classified as distractions and vice versa, which makes it challenging to generalise findings across studies, thus creating a barrier for knowledge generation (Sasangohar, Donmez, Trbovich & Easty, 2012).

Table 4: Selected example of definitions of task interruptions presented throughout the healthcare literature.

Reference	Definition of Interruption
Chisholm et al (2000)	*"An interruption was defined as any event that briefly required the attention of the subject but did not result in switching to a new task."* *"A break-in-task was defined as an event that not only required the attention of the physician for more than 10 seconds, but subsequently resulted in changing tasks."*
Coiera et al (2002)	*"A communication event in which the subject did not initiate the conversation, and which used a synchronous (i.e., two-way) communication channel."*
Ebright et al (2003)	*"Distraction from the immediate task or issue-at-hand"*
Hillel & Vicente (2003); Ginsburg (2004)	*"An external event resulting in switching tasks"*
Alvarez & Coiera (2005)	*"A conversation-initiating interruption is a communication event that is not initiated by the observed subject and occurs using a synchronous communication channel such as face-to-face conversation or the telephone."* *"A turn-taking interruption occurs within an individual communication event, when one individual begins speaking before the other finishes. Two criteria: (a) the interrupter does not allow the other speaker to finish his/her utterance, (b) the interrupter was able to finish or continue his/her utterance."*
France et al (2005)	*"A temporary interruption was an interruption that momentarily diverted the physician's attention away from the task at hand but did not result in a break-in-task."* *"A break-in-task was a type of interruption that pre-empted one task, resulting in another task being performed."*
Persoon et al (2011)	*"An interruption was defined as when a distraction leads to a break in main task activity."* *"A distracting stimulus was defined as any event that can cause diversion from the task at hand, and a distraction was any observed behaviour indicating orientation away from the main task."*
Periera et al (2011)	*"Distraction was defined as the behaviour observed when there was diversion of attention during the execution of a primary task and/or a verbal response to a secondary task related or not related to the activity performed."*

***Note.* Adapted from (shorter version) Sasangohar, Donmez,Trbovich & Easty (2012)**

Furthermore, without a theoretically grounded and consistent definition, several confounds are apparent within much of the existing research. The operationalisation of interruptions and/or distractions guides the research undertaken. In addition, and as noted by Grundgeiger & Sanderson (2009), a theoretically underpinned definition of task interruption should consider the underlying cognitive processes either involved or impacted by the interruption (e.g., working memory, attention, inhibition) as this would help to understand the effects and guide interventions. For example, research has suggested that interruptions and distractions have very different effects on cognitive processes and performance (e.g., Altmann & Trafton, 2002, 2004, 2007; Altmann, Trafton, & Hambrick, 2014; Beaman, Hanczakowski, & Jones, 2014; Craik, 2014) and thus are likely to have different impacts on performance.Therefore, assuming the two are not distinctively different creates a misunderstanding during the interpretation of results (e.g., Healey, Sevdalis, & Vincent, 2006; McBride, 2015; Persoon et al., 2011). Differences in defining interruptions and distractions may be attributed to the minimal use of research findings from different disciplines (e.g., psychology, HF, healthcare). This PhD encompasses extended sources of literature from a variety of domains, which in turn allows for a better understanding on interruptions in safety critical healthcare settings.

In addition to the issues in the operationalisation of task interruptions, findings are often either implicitly or explicitly generalised across the healthcare context. However, the context in which interruptions or distractions occur is important to consider to fully understand the possible outcomes (Coiera, 2012; Feuerbacher et al., 2012). Much of the research surrounding interruptions and distractions within an emergency and critical care context has been undertaken outside the UK, with only a couple of studies taking place within UK hospitals. Furthermore, studies tend to only focus on one ward (e.g., Intensive Care Unit or Emergency Department; Drews, 2007; Spooner, Corley, Chaboyer, Hammond & Fraser, 2015), with samples rarely including more than two healthcare professionals (e.g., Nurses and/or Physicians; Cornell, Riordan, Townsend-Gervis & Mobley, 2011; Sasangohar, Donmez, Easty, Storey & Trbovich, 2014).

This work draws on a broad range of literature across multiple disciplines (such as healthcare, psychology, and human factors) to generate a clear distinctive definition of both interruptions and distractions. By applying these definitions across a variety of UK Emergency and Critical Care settings (e.g., Emergency Department, Acute Medical Unit, High Dependency Unit, and Intensive Care Unit) to understand their differentiating effects, this will in turn better inform future interventions aimed to improve healthcare staff efficiency, reduce error, and improve patient safety (McCurdie, Sanderson & Aitken, 2016).

Current Study

There is a wealth of theoretical and applied research exploring the effects of task interruptions, and how various characteristics may alleviate or aggravate such effects. However, when exploring the healthcare literature around clinical task interruptions key limitations include, for example, diverse operationalisation of task interruptions and minimal consolidation across disciplines in relation to advance research in this area. To generate a more holistic understanding of the characteristics and perceived impact of task interruptions by healthcare professionals, a questionnaire study was undertaken within an Emergency and Critical Care setting in a UK hospital. To help achieve the aim of this study, consideration was given to both forms of disruptions, interruptions, and distractions. The study set out to provide further insight into healthcare professionals understanding of what differentiates interruptions and distractions within healthcare. This includes exploring:

- How interruptions and distractions are defined by healthcare professionals.
- How healthcare professionals perceive the effects of interruptions and distractions in terms of performance (e.g., time delays, medical task efficiency), well-being (e.g., increased stress/workload/well-being) and patient safety (e.g., medical errors, delayed patient care).
- The characteristics of task interruptions and distractions in which healthcare professionals perceive to be the most prominent and impactful.

This study utilised mixed methods (qualitative and quantitative approaches) in order to better understand interruption and distraction within a healthcare setting. Through the inclusion of both forms of disruptions, perceptions in terms of how healthcare professionals define, and associate varying characteristics can be better understood. Such an exploratory study provides a step forward in understanding the complex nature of interruptions in healthcare, from the core definition to the varying characteristics that may moderate any negative effects.

Entry Issues and Ethical Considerations

Ethical approval was gained through the University of the West of England – Bristol Faculty Research Ethics Committee (UWE REC REF No: HAS.17.07.186), and Health Research Authority (IRAS ID: 227431; HRA REF: 18/HRA/0154). Noted below are several ethical issues that were considered during the application process and have been implemented for the purposes of this study.

Entry Issues

The original ethical proposal to the Health Research Authority (HRA) suggested that an NHS honorary research staff contract would be applied for by the lead researcher, which (if successful) would allow the researcher onto the proposed research site to approach potential participants during team briefings and access DATIX incident reports.

DATIX is a patient safety online software, where healthcare staff can voluntarily and anonymously report incidents and near misses. The individual reporter provides information on the location, if medication related the stage of the process it occurred, the nature of the error, outcome, contributory factors, and severity of incident (low = minimal risk to patient with no potential harm; severe = error could result in permanent harm or death; Irwin, Ross, Seaton & Mearns, 2011). As well as using several predefined codes to classify the incident or near miss, individuals are also given the opportunity to supply a factual description of what happened and the impact it had on the patient (Pezzolesi, Schifano, Pickles, Randell, Hussain, Muir & Dhillon, 2010). DATIX along with other forms of incident reports (e.g., paper-based systems, Medmarx medication reporting system) have been used to assess medication errors (e.g., Alrwisan, Ross & Williams, 2011), handover incidents (e.g., Farhan, Brown, Vincent & Woloshynowych, 2011; Pezzolesi, Schifano, Pickles, Randell, Hussain, Muir & Dhillon, 2010), and effectiveness of incident reporting systems (e.g., Stavropoulou, Doherty & Tosey, 2015).

The Health Research Authority and Patient Safety Team raised concerns about this proposal, highlighting the minimal time healthcare staff in safety critical settings have during team briefings, which in turn may not allow for adequate time to provide a fully informed brief/debrief of the study. Furthermore, there was scepticism of allowing an external researcher full access to sensitive data via the DATIX incident reports. Because of these concerns, it was suggested (and in turn was implemented) that the local collaborator (PhD supervisor with a senior role within safety critical healthcare settings) distributed the questionnaire to potential participants via an internal email, and the Patient Safety Team provided anonymised DATIX data that was only relevant to this research study. These practices removed the need for the researcher to be at the NHS site during any period of the study. The DATIX incident report data provided by the Patient Safety Team did not provide adequate details to make accurate comparisons in relation to the research aims. Despite best efforts made to gain access to appropriate data, there appeared to be differential views on how the research aims may be met with such data. Furthermore, due to the various degrees in which incidents were reported and classified, it was not possible to clearly identify either an interruption and/or distraction as the contributing factor of an incident. This in turn affected the quality of data provided for this research study, and whilst raising important questions for incident reporting in healthcare, the data was not included as it was not specific to the research aims.

Confidentiality and anonymity of participants/patients/hospital wards/and hospital.

Questionnaire data required participants to provide a password that can only be identified by themselves, using a predefined coding system suggested by the researcher (e.g., last two letters of their first name, their year of birth, and first two letters of their surname: IG1988WI). In addition, no personal contact details were recorded (e.g., emails, telephone numbers), and if participants required information, they could contact the researcher directly. This system ensured the anonymity of participants. Where participant and/or patient details may be visible (e.g., DATIX incident reports), these were removed by the NHS Patient Safety Team during the data extraction process before providing the data to the researcher. Sections of the questionnaire require participants to recall a critical event. Whilst instructions advised participants to not use any information that may lead to the direct identification of themselves, patients, hospital ward, and hospital, if such information was recorded it would be removed by the researcher prior to data analysis. Any dissemination of research findings would not reveal any details that may result in the direct identification of participants/patients/or hospital. Dissemination in conferences, journals, reports, and thesis, would be in its analysed form and cannot be traced back to participants. Any data collected is for research purposes only and would only be shared between members of the research team.

Data Protection

All data collated is treated in accordance with the Data Protection Act (1998). The study took place before GDPR Regulations (2018) were initiated, however guidance on the storing of personal and non-personal data has since been updated in line with these regulations. Data is being stored securely on a password protected computer, with an additional backup stored on a secure password protected external hard drive. This data would only be shared amongst the research team for reasons appropriate to the aims and research questions of the study. Data may be stored for up to 5 years for the dissemination to scientific journals and conferences, and participant anonymity and confidentiality would remain. The online version of the questionnaire was created using Qualtrics software, in which all data is safeguarded under FedRAMP security compliances, and only accessible and managed by the lead researcher.

NHS Costs

The study was designed to put no additional costs upon the NHS. The study did not interfere with everyday work practices and did not (and was not intended to) jeopardise patient safety. Participants were advised to complete the questionnaire in their own time, this may have been either before or after a working shift, or during a break period. Utilising an online questionnaire design should have aided this by providing an accessible web link that could be accessed outside the work environment. Continual liaisons with ward managers, local collaborators, and local research development offices ensured these practices applied.

Consent and right to withdrawal

Participants needed to be over the age of 18 to participate, and voluntary consent was required before they could complete the questionnaire. Where consent was not obtainable on the grounds of capacity to give consent, a guardian or legal representative would be able to give consent for their participation. The lead researcher did not have the capabilities to assess capacity to give consent, and where consent was obtained, capacity was assumed unless otherwise stated. An information sheet was provided before consent was required, providing full details of the study, and what was expected from them, which allowed participants to make an informed decision as to whether they wished to participate. The online questionnaire required a signature, and participants could not proceed without this. Within the information sheet was details relating to participants right to withdraw at any time without any given reason. If participants wished to withdraw their data after the initial data collection period, they were advised that this is possible (with their unique participant code) up until the period of data analysis, at which point it may not be possible to trace the data back.

Potential emotional and/or physical distress

There may be a risk of emotional distress and/or discomfort when completing the critical incident section of the questionnaire. This section required the reflection of a critical event that has resulted in a positive and negative patient outcome. Such negative events may invoke negative emotional response in how the participant feels about the event. To minimise this effect, the participant could recall either a positive or negative critical incident, and therefore were not obliged to provide details of a negative incident. If participants did experience any emotional and/or physical discomfort as a direct result from their participation in the study, they were advised to contact the lead researcher and/or delegated free support services provided. Details for both were in the debrief form given to the participant at the end of the study. Even if participants withdrew from the study prior to the end, a debrief form was still provided.

Recruitment and data availability

There were several difficulties experienced in the data collection of this study that has result in limited ability to provided exploratory analysis beyond descriptive statistics. Some of these difficulties are briefly explained below, however, the original methodology and justification for the research is still provided in subsequent sections. This is done so to provide context to the justification and proposed approach to this study.

The questionnaire undertook two iterations. There were several issues in response rates to the questionnaire (see Table 5). To address this and thus increase the response rate, and the local collaborator gained feedback from healthcare professionals who had either completed the questionnaire or had seen it but not completed it. The feedback highlighted two main issues. Firstly, participants felt confused about the definition between a task interruption and distraction, despite a definition being optionally provided (participants had to click to show the definition) at the start of each question with a context specific example for each. Such confusion may be attributed to the definitions provided by research conflict with how they perceive an interruption or distraction. To explore this possibility an addition section was added where participants were able to provide a definition of what they felt an interruption and distraction was.

Table 5: Response rate for Study one split across each section.

Questionnaire Section	Response Rate (% of the 50 who responded to the study invite)
Demographics	33 (66)
Participant definition of interruption and distraction	22 (44)
Tasks interrupted/distracted	33 (66)
Source of interion/distraction	33 (66)
Reason for interruption/distraction	22 (44)
Relevance of interruption/distraction	17 (34)
Shifts interruptions/distractions occur	17 (34)
Specific time periods within shifts	12 (24)
Individual effects	12 (24)
Magnitude of error	10 (20)
Handling techniques	8 (16)
Critical incidents	No responses

There was also an issue with the time it took to complete the questionnaire, noting that many of these healthcare professionals have very little spare time outside the working shift to complete the measure. To reduce the time strain associated with the completing the questionnaire, the Critical Incident section was made optional. This significantly reduced the time needed to complete; however, none of the participants opted to complete this section. The latest version of the questionnaire is available in Appendix 1.

Despite such changes, there were still challenges in the recruitment of an adequate sample to perform any causal analysis. Whilst continuing to push on recruitment through reminder emails sent by the onsite collaborator, after over a year of hitting barriers, it was decided to stop recruitment and continue with the data already collected. Much of the issues experienced in recruitment could be related to various aspect of the context in which recruitment was taking place and understanding on the nature of the study.

The DATIX incident reports provided by the participating hospital did not contain sufficient information on the nature and reason a clinical error occurred. There appears to be numerous DATIX categories missing from the sample provided, and upon further exploration it was deemed appropriate for this research by the participating hospital. Whilst I found this frustrating given the time invested to gain appropriate ethical approval, I was not able to undermine their professional opinion. I do feel that the restrictions on individuals outside a healthcare profession (e.g., psychology students), was a barrier both in terms of gaining appropriate ethical approval for research, and access to the necessary tools and support to complete the research. This seemed particularly obvious in terms of this research project, whereby the nature of the research appeared confusing and at times not beneficial to the organisation. This was largely due, as quoted by a healthcare professional, ‘interruptions are expected and part of the work environment that staff should expect’. Whilst this is indeed true, it undermines the importance of understanding the nature of interruptions in a healthcare context, and thus improving work practices to minimise clinical errors. It may also pose a barrier to undergraduate and postgraduate researchers outside of the healthcare context, where it may become challenging to work alongside healthcare professions for a more holistic approach and understanding.

Methodology

Design and Justification

Within a healthcare setting, the utilisation of qualitative methodologies has become a traditional approach when investigating interruptions and distractions (Coiera, 2012). The use of different qualitative methodologies within a healthcare setting provides opportunities for knowledge generation, and this is no different when studying interruptions and distractions within safety critical healthcare settings. Methodologies that have been employed to investigate interruptions and distractions in an safety critical healthcare setting include; observations (e.g., Kosits & Jones, 2011., Kalisch & Aebersold, 2010., Allard, Wyatt, Bleakley & Graham, 2011, Jothiraj, Howland-Harris & Moppett, 2013; Healey, Sevdalis & Vincent, 2006), interviews (e.g., Berg, Florin, Ehrenberg, Ostergren, Djarv, Katarina & Goransson, 2016; Sanshera, Franklin & Dhillon, 2007), staff diaries (e.g., Balas, Scott & Rogers, 2004), questionnaires (e.g., Sevdalis, Forrest, Undre, Darzi & Vincent, 2008), incident reports (e.g., Hicks, Sikirica, Nelson, Schein & Cousins, 2008), or a combination of methods (e.g., Berg, Kallerg, Goransson, Ostergren, Florin & Ehrenberg, 2013). It appears that observational data collection methods are the most prominent method utilised when studying interruptions and distractions. In their review of interruptions and distractions in acute care nursing environments, Hopkinson and Jennings (2012) identified 44 articles each utilising various data collection methods. Of these, 28 adopted an observation technique, 8 interviews, 4 used focus groups, 2 used questionnaires, and 1 used a record review and self-report tracking log. Of the observational studies, 10 combined this method with other data collection methods.

Observational studies allow for the investigation of interruptions and distractions in the current context, however only so many events can be reliably observed by the observer at one time. This has led some studies only focusing on certain characteristics, with minimal acknowledgement to other factors that are important in understanding the multifaceted nature of interruptions and distractions in safety critical healthcare settings (Ratwani, Hettinger, Brixey, Rivera & Colligan, 2014). For example, some studies have explored the frequency and source of interruptions and distractions (e.g., Hall, Ferguson-Pare, White, Besner, Chisholm, Ferris, Fryers, Macleod, Mildon & Pederson, 2010; Kellogg, Wang, Fairbanks & Ratwani, 2016). However, the reason for the interruption and/or distraction may also be important, such as its relevance to the task at hand or patient care (e.g., interrupted to gain critical patient information for the current task at hand, or the sound of an emergency alarm for the arrival of patient requiring emergency care; Mamykina, Carter, Sheehan, Hum, Twohig & Kaufman, 2017; Berg, Florin, Ehrenberg, Ostergren, Djarv & Goransson 2016). Understanding variables such as relevance and reason for interruptions and distractions are difficult to observe, with such variables open to interpretation by the observer which may be influenced by the observers' biases towards interruptions and distractions (e.g., McCurdie, Sanderson & Aitken, 2017). The use of interviews and staff diaries may provide an opportunity to capture a wider range of contributing latent variables and provide some insight into those that are difficult to observe. However, interviews may put restrictions upon the sample size, given certain time constraints and access to appropriate samples (Choo, Garro, Ranney, Meisel & Guthrie, 2015), while diaries may be more open to missed opportunities for logging data within a busy context. Apart from staff diaries and incident reports, other methods make it difficult to make associative links to errors, where assumptions are often made if an error proceeds the interrupted or distracted task (Grundgeiger & Sanderson, 2009).

To best answer the proposed research questions, the following study has adopted a mixed method approach utilising questionnaire and DATIX incident reports. The use of a questionnaire which was in an online format (Qualtrics), minimised perceived time pressures participants may feel by allowing them to complete the questionnaires in their own time. Furthermore, questionnaires may be less susceptible to biases (e.g., social desirability, experimenter bias) due to the self-administration in an online format resulting in less involvement of the researcher (Edwards, 2010). A questionnaire design allows for the gathering of data from a broader representative sample and in a variety of settings, allowing results to be more generalizable to the specific context (Kelley, Clark, Brown & Sitzia, 2003). There are some limitations to using a questionnaire within a healthcare context. Response rates for healthcare professionals is a recognised challenge across the literature (e.g., McLeod, Klabunde, Willis & Stark, 2013), which in turn can potentially impact the sample size and increases the likelihood of response bias (Cho, Johnson & VanGeest, 2013). Several methods have been proposed to increase response rates, one of which is the use of an online questionnaire, however there is also the risk of the email being recognised as spam which may also change the response rate (Cunningham et al., 2015). Another issue is the possible ambiguity on what is expected from participants, or how questions should be answered (Evans & Mathur, 2005). This may be a particular issue when it comes to understanding what constitutes an interruption or distraction, given the mixed definitions and understanding across professional domains (Grundgeiger & Sanderson, 2009).

The use of DATIX incident reports provided added support to the questionnaire data by providing detailed accounts of critical incidents, along with details surrounding factors that may be associated with the event. Whilst DATIX incident reports only supply details of incidents that have resulted in a negative outcome, there would be an opportunity within the questionnaire for participants to report on a critical incident that has resulted in a positive outcome.

The questionnaire allows for the quantification and association of certain characteristics, it is difficult to associate such data with errors. To further support these associations, and supply some insight into possible associations to errors, the use of a Critical Incident Technique (CIT; Flanagan, 1954) will be incorporated within the questionnaire, and the analysis of DATIX incident reports will be utilised to collect qualitative data. The CIT is a qualitative research tool that can be utilised to gain insight into an individual's perspective of an experienced critical event. The anonymity of CIT's allows the individual to freely express their thoughts and feelings on the incident itself, why it happened, and the consequences of the event. Whilst they allow for the measurement of abstract constructs, the CIT also gives the individual the opportunity to be heard with emphasis on how important their experiences are (Marrelli, 2005). CIT has been used within a healthcare context to investigate nursing experience and patient care (e.g., Hosie, Agar, Lobb, Davidson & Phillips, 2014), healthcare professionals' beliefs in certain issues (e.g., Taylor, Bradbury-Jones, Kroll & Duncan, 2013), and understanding the causes of medication errors (e.g., Keers, Williams, Cooke & Ashcroft, 2015). CIT is often used as a data collection tool during observational studies, however in may also be utilised as a retrospective data collection tool incorporated within questionnaires, supplying information on incidents that are recent (Urquhart, Light, Thomas, Barker, Yeoman, Cooper, Armstrong, Fenton, Lonsdale & Spink, 2003). Adequate reliability and validity for CIT has been reported (Koch, Strobel, Kici & Westhoff, 2009; Ronan & Latham, 1974), therefore CIT seems to be a suitable method on gathering a healthcare professional's perspective of effective and ineffective incidents involving interruptions and distractions within safety critical healthcare settings (Butterfield, Borgen, Amundson & Maglio, 2005).

Sample and Setting

Healthcare staff is a broad term by which each job role varies in the degree of patient interaction, specialised training that may be needed, and general job duties that the individual is expected to be involved in, however all share a commonality in that patient safety is the forefront of their job. To aid in the clarification of the targeted sample, the Standard

Occupational Classification (Office of National Statistics, 2010) was used to define the selected sample. The targeted sample is all healthcare staff who are over the age of 18 and are either a medical practitioner (e.g., anaesthetist, consultant, doctor, paediatrician, radiologist, surgeon), nurse (e.g., staff nurse, student nurse, registered nurse at all band/grading levels), or medical secretary (e.g., medical administrator or secretary). In addition, the targeted sample must currently be employed or recently employed within one (or more) of the three Emergency and Critical Care settings (Intensive Care Unit/ICU, High Dependency Unit/HDU, Emergency Department/ED). Such settings were identified as some of the most safety critical healthcare settings, based upon the complex socio-technological processes needed to ensure patient safety is kept and errors are minimised (e.g., Gurses, Winters, Pennathur, Carayon & Pronovost, 2012; Perry, Wears & Fairbanks, 2012).

The proposed sample size for the questionnaire is the proportion of response rates of healthcare staff the onsite local collaborator electronically (via internal email) sent the questionnaire too. Response rates to online surveys in healthcare are suggested to average at 38% (Cho, Johnson & VanGeest, 2013). The questionnaire was sent to 105 healthcare professionals within the Emergency Department (including Accident and Emergency) and 120 Critical Care (including Intensive Care Unit and High Dependency Unit) healthcare employees which was formed of students, nurses, and other medical employees (e.g., doctor, anaesthetist, consultant etc). With consideration of the average response rate (38%), it was predicted that the response rate would be 86. Actual response rate was 50 (22.22%), with questionnaire completion varying throughout.

The NHS Patient Safety Team agreed to provide DATIX incident reports for three hospital wards (Emergency Department, Intensive Care Unit, and High Dependency Unit) for a period of six months. Such incidents received do not reflect the true number of incidents reported, as only those that were believed relevant to the current study were provided. Within this period a total of 605 incidents were perceived to be relevant to the current study and contained a descriptive account of the incident, the predefined DATIX category it fell under, the date the incident occurred, hospital ward, and degree of harm.

Materials

The questionnaire was designed to collect both quantitative and qualitative data. Quantitative data was collected on questions relating to the nature and characteristics of interruptions and distractions and was guided by previous research including; the source of interruptions and distractions (e.g., Hall et al, 2010; Healey, Primus & Koutantji, 2007) , the type of task that is interrupted or distracted (e.g., Westbrook, Coiera, Dunsmuir, Brown, Kelk, Paoloni & Tran, 2010), frequency of interruption and distraction (e.g.,; Healey, Sevdalis & Vincent, 2006), shift pattern they occur in (Weigl, Muller, Zupanc, Glaser & Angerer, 2011), reason for interruption or distraction (e.g., Berg, Kallberg, Goransson, Ostergren, Florin & Ehrenberg, 2013), the effect they have on the individual, and techniques the individual has engaged in to help handle interruptions and distractions (e.g., Colligan & Bass, 2012). Such questions will be quantified using several different predefined measurements. A 5-point Likert type scale ranging from 1 (never) to 5 (always) is used to quantify answers relating to shift pattern, the source of interruption and distraction, the effect interruptions and distractions have on the individual, and the techniques and effectiveness of techniques they have used in handling interruptions and distractions. Questions relating to frequency and relevance of interruptions and distractions require participants to attribute a percentage value (0% = not relevant, 100% = always relevant). Given the diversity of the number of clinical tasks (current task at hand) that may be interrupted or distracted, or the reason for the interruption or distraction, questions relating to these require participants to list the three most common tasks and reasons. These pre-defined questions allow for the generation of descriptive data that will supply insight into associations between the nature and characteristics of interruptions and distractions from the perspective of healthcare staff.

Qualitative Data Analysis Technique

Qualitative data collected from the CIT and DATIX incident reports were going to be analysed using a thematic analysis, which aims to identify, analyse, and report emerging themes within the data collected (Boyatzis, 1998); however, as state previously due to the limitations in the DATIX data provided, and no respondents for the CIT, the following analysis was that proposed should this data have of been available. Thematic analysis is not theoretically constrained to an epistemological position as opposed to other qualitative methods (e.g., grounded theory) allowing for flexibility and provides the opportunity for obtaining detailed accounts of data (Braun & Clarke, 2006). The thematic analysis will be deductive, that is theoretically based as opposed to inductive, as it is driven by the analytic interest of effective and ineffective interruptions and distractions, therefore coding of the data will be specific to the research question (Braun & Clarke, 2006). There are some criteria for what may be considered as an accurate self-report based upon the quality of the incident reported. Due to the subjective nature of qualitative research, Flanagan (1954) proposed a standardised procedure to analysis critical incidents, in which the same procedure will be used with the DATIX incident reports. Firstly, to maintain accuracy, for an incident to be included it must meet the following criteria: involve an interruption or distraction, they consist of some form of proceeding description leading up to the incident, a detailed description of the incident itself, and an account of either a positive or negative outcome because of the incident (Butterfield, Borgen, Amundson & Maglio, 2005). Data will then follow a categorisation process starting with a frame of reference, which refers to a broad categorisation of critical incidents which will reflect the research aims. The next stage involves category formulation, which entails the sorting of critical incidents into sub-categories. Category formulation involves the construct of categories that are created using titles and brief descriptions and require continuous monitoring for revising and re-allocating incidents if necessary. Once critical incidents have been allocated correctly, the next stage involves specificity, which involves the appropriate level of analysis based upon the aims of the study and intended use of data (Hughes, Williamson & Lloyd, 2007).

Results

Demographics

Of the 50 responses to the questionnaire, 33 provided demographic details including age, gender, and employment details. The mean age of respondents was 34.4, whereby 23 were Female. Figure 1 shows the frequency of responses by healthcare profession. The highest proportion of responses were received by Nurses (16 responses), and this included of Nurses Band 5, 6,7 and Matron (Chief Nurse). The second highest response rate was from Doctor's (11), although this includes a more extensive range of medical banding preferably due to the on-going specialist medical training Doctors are likely to receive. These include Junior Middle Grades (e.g., ST1/2), Senior Middle Grade (e.g., ST3-8) and Consultant. The remaining responses comprised of Medical Students (4) who were currently studying a post-doctoral degree, a Clinical Fellow, and a Physician (Table 6).

Table 6 Frequency of survey responses split by healthcare profession.

Healthcare Profession	**% Of total response**
Other	0%
Doctor_ST5	3.03%
Consultant	3.03%
Physician_ST6	3.03%
Registrar_ST6	3.03%
Doctor Registrar	3.03%
Clinical Fellow	3.03%
Staff_Nurse_B6	6.06%
Doctor_ST6	6.06%
Senior_Nurse_B7	9.09%
Matron	9.09%
Doctor_ST3	9.09%
Trainee Doctor	9.09%
Student Nurse	12.12%
Staff_Nurse_B5	21.21%

Whilst there was an initial intention to make comparisons across different safety critical healthcare departments, the majority of responses were received from those who work within the Emergency Department (see Table 7), not allowing for meaningful comparisons to be made.

Table 7: Frequency of survey responses split by healthcare profession.

Hospital Ward	% Of total responses
Emergency Department	75.76%
Intensive Care	12.12%
Accident Emergency	9.09%
Other	3.03%

Participants Definition of Task Interruption and Distractions

Despite providing a grounded and consistent definition of a task interruption and distraction that could be viewed throughout the questionnaire, the feedback received indicated that response rate was impacted to a lack of understanding on what was meant by each. When making changes to the questionnaire to account for some of the feedback received, a question asking participants how they would define a task interruption and distraction was included (Table 8).

Table 8: Definitions of task interruption and distractions provided by respondents in Study 1.

Participant (Anonymised)	Interruption Definition	Distraction Definition
1	*'When you are actually stopped in the middle of completing a task.'*	*'Something going on in the background that could cause you to lose concentration on the task you are performing.'*
2	*'When someone or something stops an action for a short period'*	*'When someone or something interrupts your attention'*
3	*'When somebody disturbs what you are doing'*	*'When your attention is altered by something someone may be doing e.g., background noise'*
4	*'Having to stop the task being undertaken'*	*'Something that interrupts concentration'*
5	*'When i am stopped of doing my job by an interference'*	*'When my concentration in my job, is diminished by an interference'*
6	*'A physical or verbal act that stops you from doing your current task'*	*'A physical or verbal act that takes your attention away from your task but allows you to continue'*
7	*'Someone else initiating, e.g., talking to you when you're working'*	*'Yourself initiating being distracted, e.g., going on Facebook to look at a video someone has tagged you in'*
8	*'Something that distracts you from the task at hand'*	*'Something that takes your mental attention away from the activity you were focussing on'*
9	*'Asked a question'*	*'Anything which pulls your attention away from what you are doing'*

10	*'Stopping what I am doing'*	*'In the background so I am not concentrating'*
11	*'E.g., Colleagues asking for support. Patient relative telephone calls. Giving colleagues support with technical tasks. Teaching / supervising medical students'*	*'E.g., Being thirsty. Feeling unwell. Feeling annoyed. Being upset.'*
12	*'A direct attempt to gain your attention for a task while a current task is in process'*	*'Events occurring in your environment that may gain your attention which a current task is in action'*
13	*'An action or occurrence that means have to stop doing what was in the middle of two e.g., make a decision about something else'*	*'Other activities ongoing around preventing one from being able to fully concentrate on the task in hand'*
14	*'Being interrupted such as being asked a direct question'*	*'Noise or visual disturbance that can take your attention away'*
15	*'Someone purposely coming to you'*	*'Background activity'*
16	*'Someone/something physically changing/ making your change your thoughts of your original task'*	*'Noise, sounds, environment'*
17	*'An issue or item requiring your attention whilst you are trying to complete a task'*	*'A sensory input that interrupts your thoughts and or completing a task- a noise, someone speaking to you, a phone ringing continuously and not being answered'*
18	*'Something that stops you from completing a task you are trying to do.'*	*'Something in the background that catches your attention while you are trying to do something.'*

19	*‘Something, mainly external influence that takes attention away from the task in hand, to something new.’*	*‘A more minor version of the above that accidentally disrupts someone's focus momentarily.’*
20	*‘An action or incident that terminates a person or systems flow of action or purpose’*	*‘An action or incident that interrupts and delays the achievement of an intended goal’*
21	*‘An external element which stops you from your current task’*	*‘Elements not directly related to the task at hand vying for attention’*

The definitions provided by participants highlight how interruptions and distractions are not always viewed similarly, and such views varying from person to person. For example, some viewed an interruption as a break in task whilst at the same time defining a distraction as an interruption (e.g., participant 4), whilst others would highlight specific details that separate an interruption and distraction. These include, interruptions occurring purposefully as opposed to distractions being more about environmental sound (e.g., participant 15 & 16), or interruptions were initiated by anyone external, while distractions are initiated by oneself (e.g., participant 7). Whilst there were such diverse perceptions of what may constitutes an interruption or distraction, participants were encouraged to provide answers based upon the definitions provided. What these perceptions highlight is the complex nature of interruptions and distractions, and why it is important to have firm operationalised definitions when researching.

Tasks Interrupted and Distracted

Participants were asked to provide three medical tasks they felt were interrupted and distracted the most. Answers for this question were grouped into main themes, whereby each theme had several sub-tasks that were coded within the main theme. Table 9 highlights the frequency of responses that participants provided. Clinical documentation was the most frequent cited task the participants felt was interrupted and distracted. Clinical documentation tasks included writing notes, completing incident forms, and writing care plans. Medication administration was the second most frequent task perceived to be interrupted, while clinical advice was viewed as the second most distracted task. Finally, the third most frequent task that was interrupted was personal patient care. This included checking in and talking to patients and relatives. For distractions, general clinical procedures outside medication administration were the third most frequent task distracted.

Table 9: Frequency of responses to clinical task most likely to disrupted by task interruptions and distractions.

Task Interrupted	Frequency of Response (%)		Task Distracted	Frequency of Response (%)
Clinical Documentation	23.75%		Clinical Documentation	23.91%
Medication Administration	21.25%		Clinical Advice	19.56%
Personal Patient Care	16.25%		General Clinical Procedure (not administering medication)	15.21%
Clinical Advice	12.5%		Personal Patient Care	13.04%
General Clinical Procedure (not administering medication)	11.25%		During Shift Handover	8.69%
Patient Monitoring	6.25%		Checking Test Results	8.69%
Checking Test Results	6.25%		Medication Administration	6.52%
During Shift Handover	2.5%		Computer Based Task	4.34%

Source of Interruption and Distractions

Participants were asked to rate various interruption and distraction sources based upon the likelihood in which they may occur (Table 10). There is no surprise that various sources of task interruptions and distractions occur within the healthcare setting. The results below indicate that predominantly, most interruptions are to be initiated by fellow clinical professionals, particularly Doctors and Nurses. For distractions, department phones and fellow Nurses were the most likely source. Distractions and interruptions due to patient interactions were not included as an individual category due to the number of occurrences being minimal (only once) for them being reported as a source of interruption or distraction.

Table 10: Likelihood of task interruptions and distractions being initiated through various sources.

Disruption	**Source**	**Likelihood of Occurrence (%)** **Low** **Moderate** **High**				
		Never	**Rarely**	**Sometimes**	**Often**	**Almost Always**
Interruption	Admin Staff	**0%**	**45.45%**	**36.36%**	**18.18%**	**0%**
Distraction		**23.52%**	**29.41%**	**23.52%**	**17.64%**	**5.88%**
Interruption	Nurse	**0%**	**4.76%**	**9.52%**	**47.61%**	**38.09%**
Distraction		**4.54%**	**13.63%**	**27.27%**	**27.27%**	**27.27%**
Interruption	Doctor	**9.09%**	**0%**	**22.72%**	**54.54%**	**13.63%**
Distraction		**9.09%**	**13.63%**	**36.36%**	**27.27%**	**13.63%**
Interruption	Anaesthetist	**31.81%**	**45.45%**	**9.09%**	**9.09%**	**4.54%**
Distraction		**40.90%**	**36.36%**	**18.18%**	**4.54%**	**0%**
Interruption	Paediatrician	**100%**	**0%**	**0%**	**0%**	**0%**
Distraction		**90.47%**	**9.52%**	**0%**	**0%**	**0%**
Interruption	Other Clinical Staff	**4.54%**	**40.90%**	**45.45%**	**9.09%**	**0%**
Distraction		**18.18%**	**59.09%**	**13.63%**	**9.09%**	**0%**
Interruption	Non-Clinical Staff	**9.52%**	**52.38%**	**23.80%**	**9.52%**	**4.76%**
Distraction		**4.54%**	**45.45%**	**45.45%**	**0%**	**4.54%**
Interruption	Department Phone	**0%**	**4.54%**	**18.18%**	**27.27%**	**50%**
Distraction		**0%**	**4.54%**	**13.63%**	**45.45%**	**36.35%**
Interruption	Personal Phone	**59.05%**	**36.36%**	**4.54%**	**0%**	**0%**
Distraction		**45.45%**	**27.27%**	**18.18%**	**9.09%**	**0%**

Interruption	Computer Related	**9.09%**	**13.63%**	**27.27%**	**36.36%**	**13.63%**
Distraction		**18.18%**	**27.27%**	**18.18%**	**27.27%**	**9.09%**
Interruption	Clinical Equipment	**0%**	**36.36%**	**36.36%**	**27.27%**	**0%**
Distraction		**18.18%**	**27.27%**	**31.81%**	**18.18%**	**4.54%**
Interruption	Email	**68.18%**	**22.72%**	**4.54%**	**4.54%**	**0%**
Distraction		**63.63%**	**27.27%**	**9.09%**	**0%**	**0%**

Reasons for Interruption and Distraction

Participants were asked to provide examples for the reason interruptions and distractions occurred. Table 11 provides a representation of the most frequent reasons reported for being interrupted and distracted. Providing assistant to nursing staff appeared to be the most frequent reason participants felt they were interrupted. What's not clear is the urgency of such assistance required. Checking clinical results appeared to be the second most frequent reason reported, while manager updates, and relative queries often occurred. For distractions, general department noise was the most frequent reason. Telephone calls and fellow staff closely followed this have conversations on the ward.

Table 11: Perceived reason for interruption and distractions.

Interruptions	
Reason	**% Of total responses**
Disruptive Patient	4.55%
Telephone Calls	10.61%
Nursing Staff Assistance	27.27%
Clinical Results Checking	15.15%
Patient Asking for Assistance	10.61%
Managers Updates	9.09%
Requesting Patient Transfer	1.52%
Relative Queries	7.58%
Prescribing Drug	3.03%
Alarms	1.52%
Lack of Resource	4.55%
Urgent Task	3.03%
Staff Conversations	1.52%
Distraction	
Disruptive Patient	10.53%
Telephone Calls	15.79%
Alarms	12.28%
Nursing Staff Assistance	8.77%
Staff Noise	1.75%
Visitors	1.75%
Department Noise	19.30%
Staff Conversations	15.79%
Urgent Task	7.02%
Mind Wandering	1.75%
Lack of Resource	5.26%

Individual Effects of Interruptions and Distractions

To gain some insight into the perceived effects of interruptions and distractions that healthcare professionals may have experienced, they were asked to rate (1 = Never to 5 =

Always) how often common errors cited in the literature were experienced (Table 12). On average, respondents reported that interruptions were more likely to influence them compared to distractions. Both time to resume the task after an interruption and time to complete the primary task were the most likely effect. For distractions, respondents perceived those distractions increased stress and fatigue.

Table 12: Average response to perceived individual effects task interruptions and distractions may have.

Interruption Effect	Average Response		Distraction Effect	Average Response
Resumption Time Delay (Interruption Only)	4.58		Resumption Time Delay (Interruption Only)	N/A
Longer to complete task	4.5		Longer to complete task	3.18
Forgetting to resume primary task (Interruption Only)	2.75		Forgetting to resume primary task (Interruption Only)	N/A
Forgetting Information	2.9		Forgetting Information	2.91
Increased Stress	3.9		Increased Stress	3.5
Increased Fatigue	3.83		Increased Fatigue	3.33
Ability To Multitask	3.08		Ability To Multitask	2.75
Increase Work Efficiency	2.33		Increase Work Efficiency	1.83
Increase Errors in Process	3.5		Increase Errors in Process	3.33

Interruption and Distraction Handling Techniques

To understand some of the behavioural strategies healthcare workers may use when faced with interruptions and distractions, and also how they perceive their effectiveness, participants were asked to rate various strategies along with how effective they felt it help (Table 13).

Table 13: Average use and effectiveness of interruption and distraction handling techniques (Higher represents increased effectiveness/use).

Technique	**Average use for handling interruptions**	**Average effectiveness of technique**	**Average use for handling distractions**	**Average effectiveness of technique**
No/minimal interruption/distraction zone (e.g., quiet zone)	1.37	1.12	1.37	1.12
‘Do not interrupt/distract’ clothing (e.g., fluorescent vests)	1.12	1.5	1.12	1.15
‘No interruption/distraction’ advertisements (e.g., posters, signs, cones)	1	1	1.37	1.37
Diversion strategies (e.g., pre-arranging for other staff to attend to non-emergency interruptions)	1.5	1.62	1.5	1.62
Process strategies (e.g., checklists to aid a process)	3.25	2.62	3.37	2.75
Memory strategies (e.g., keep notes to aid resumption)	3	3.12	2.75	2.12
Use of technology (e.g., visual cues to aid resumption)	2.12	2.12	2	2.12
Interruption handling strategies (e.g., prioritising)	3.37	3.12	2.87	2.75

Summary

The following exploratory study was undertaken to better understand:

- How healthcare professionals define interruptions and distractions.
- How healthcare professionals perceive the effects of interruptions and distractions in terms of performance (e.g., time delays, medical task efficiency), well-being (e.g., increased stress/workload/well-being) and patient safety (e.g., medical errors, delayed patient care).
- The characteristics of task interruptions and distractions in which healthcare professionals perceive to be the most prominent and impactful.

Whilst there were significant issues throughout this exploratory study in terms of, recruitment, questionnaire responses, and access to DATIX incident reports as previously highlighted, there are some key findings and implications from the data collected.

Through understanding task interruptions from the perspective of healthcare professionals, it allows for a better understanding of their roll in clinical errors with consideration given to context specific work processes, and in-turn better inform the design of appropriate interventions. One step towards this, would be through the generation of a consistent definition of what constitutes an interruption within the domain under investigation. This could be beneficial in both supporting the research being conducted, and aid healthcare professionals' perceived consequences of interruptions and distractions (both negative and positive). Currently, definitions across the literature vary from study to study, often to support the research question being explored. Such operationalisations are important to clearly distinguish the underlaying cognitive processes being explored, ensuring that it is indeed interruptions and not distractions under investigation. Whilst much of the past literature provides a definition of task interruptions, the lack of agreement has resulted in inconsistent definitions making it difficult to draw accumulated evidence. This is further exaggerated within the healthcare literature, which may be attributed to heterogeneous work areas, multi-interplaying factors and more complex demands on data collection resulting more studies that differentiate (Grundgeiger & Sanderson, 2009).

The responses provided in this study by participants in relation to how they define interruptions and distractions further highlights difficulties in a consensus of what constitutes either. This is particularly problematic when proposing interventions to minimise disruptive effects (e.g., no interruption zones), as how they are perceived various depending on the healthcare professional. There either needs to be a well-defined, context specific, and consistent definition to support the implementation of interventions, or interventions that are not retaliate upon various perceptions of interruptions and distractions (e.g., training in cognitive strategies). Furthermore, such perceptions should be accounted for within qualitative approaches (e.g., interviews, focus groups) as they may confound the significance of interpretation of outcomes.

In relation to the characteristics, and handling of task interruptions, whilst it's difficult to make any strong conclusions, there were some trends that support the proceeding task design and experimental approach. Medication administration was one of the most frequent tasks perceived to be interrupted by healthcare professionals. This is in-line with the past literature, where most of the healthcare interruption literature focuses on the administration of medication. The frequency reported in this study supports the extent of the issue reported in past literature, and further supports the need to better understand task interruptions during the medication process. Another observation from the data was that the main source of interruptions was by fellow Doctors and Nurses. This is no surprise giving the multifaceted nature of the healthcare environment, where healthcare professionals rely upon the interactions with fellow employees. What is not clear, is the urgency of such interruptions, and the timing of when they occur (e.g., during or after medication administration). Both are crucial factors to consider. Firstly, interruptions are at times required in a healthcare setting, specifically if the interruption is urgent in terms of medical priority. Secondly, awareness in the timing of the interruption could minimise the negative impacts of the interruption on the current task at hand. Therefore, there is an opportunity to further explore interruptions initiated by Nurses, and the urgency of the interruptions whilst controlling for the timing of interruptions (e.g., through experimental counter balancing). Finally, the most used and effective strategies to handling task interruptions included process strategies (check lists to aid a process) and memory strategies (keep notes to aid task resumption). The use of both strategies may be task specific, as some tasks may lend themselves better to either strategy. Interestingly, both strategies are behavioural, in that they require a conscious action to prevent the disruptive effects of task interruptions. What is unclear is the environmental constraints of the conditions in which the strategies may be successful, and the flexibility they may have across tasks in the healthcare work setting.

The preceding chapters focus on the development of a medication pre-administration task, and context specific interruption stimuli to further explore the effects of task interruptions.

Whilst the experiments were not solely dependent upon the outcome of the exploratory study, the trends identified do lend additional support. Firstly, interruptions during the medication administration are problematic, however much of the past literature explores the negative outcomes retrospectively. The proposed task takes a different approach, in developing a context specific experimental task that allows for the exploration of task interruption before medication is administered. Furthermore, interruption factors including those commonly cited across the literature (e.g., complexity, frequency, and source), and those that may be specific to a healthcare context (e.g., urgency and emotional valance) will be explored. Finally, the experiments will explore the utility of a novel intervention in the form of improving participant behavioural strategies at a cognitive level to mitigate the negative effects of task interruptions.

Chapter 4: Experiments 1-3 The development of the CAMROSE Medication Pre-Administration Task, and Clinical Decision-Making Task to explore commonly cited characteristics of task interruptions.

Introduction

Findings from healthcare and psychological literature, as well as findings from the questionnaire conducted here (see Chapter 2), indicate a gap in terms of understanding the cost of task interruptions in relation to errors that occur across different contexts. Much of the previous research provides a wealth of understanding of the cognitive underpinnings of task interruptions, and their potential effects in the real world. However, despite such informative findings, when attempting to reduce the negative effects of clinical task interruptions, particularly during the administration of medication, current methods tend to have a limited effect. Likewise, methods recommended based on findings within the psychological literature do not always fit well into the dynamic healthcare setting. This chapter focuses on the development and validation of an experimental and interruption task that allowed for further exploration and insight into interruption characteristics and intervention. Designing a naturalistic experimental task both in terms of a primary and interruption task, it allows for exploration of task/context-specifics and interventions that may be better tailored to such conditions.

Clinical task interruptions have been recognised as a contributing factor to the manifestation of clinical errors (Institute of Medicine, 1999). Such interruptions are not unusual given the socio-technical system in which healthcare environments usually operate within, which may often be ‘interrupt driven’ in that healthcare professionals deal with interruptions as part of their day-to-day work schedule (Brixey, Robinson, Turley & Zhang, 2007). Healthcare professionals are reliant upon the successful interaction of multiple work system factors (e.g., technology, organisational, patients, and healthcare professionals) to ensure that acceptable treatment and patient safety is maintained (Werner & Holden, 2015). Such dynamic healthcare environments are highly demanding of the expertise of healthcare professionals, with such demands often coming with limited time constraints. Several healthcare studies have supported the notion of interruptions as a critical contributing factor to clinical errors (e.g., Biron, Carmen, Loiselle & Lavoie-Tremblay, 2009) including a negative impact on clinical task completion time (e.g., Westbrook, Coiera, Dunsmuir, Brown, Kelk, Paoloni & Tran, 2010) with some tasks not being completed (e.g., Collins, Currie, Patel, Bakken & Cimino, 2007), and increases both the risk of medication errors occurring and severity of error (e.g., Westbrook, Woods, Rob, Dunsmuir & Day, 2010).

It is widely recognised that given the dynamic healthcare environment; medication errors do not arise in isolation. While many contributing factors can occur throughout various stages of the healthcare system (e.g., Karavasiliadou & Athanasakis, 2014), the contributing role of clinical task interruptions to medication errors have been well documented (Johnson et al, 2017). Such interruptions are inevitable within healthcare, and at times may be necessary for the quality of patient care (McGillis Hall, Pedersen & Fairley, 2010). Despite such factors, a range of interruption characterihass have been identified throughout both the psychological and healthcare literature that may exacerbate the effects during the administration of medication. However, to better understand such effects during such medical processes, there is a need to have some representativeness of both the primary and interruption task during experimental investigation.

It's important to recognise that both qualitative and quantitative methodological approaches are important in advancing knowledge in understanding the effects of clinical task interruptions in the healthcare setting. There is evidence within the literature that attempts are being made to improve qualitative methodologies when exploring interruptions in complex systems such as healthcare. For example, McCurdie, Sanderson, Aitken & Liu (2017) proposed a Dual Perspective Method to explore clinical task interruptions. This approach builds upon current data collection methods (particularly observational methods) and suggests that to best understand the effects of clinical task interruptions, one must explore it concurrently from the perspective of both the interrupter (e.g., the source of the interruption) and the individual being interrupted (e.g., the healthcare professional being interrupted).

Such an approach would potentially validate the observed characteristics of clinical task interruptions whilst considering the broader context in which they arise, however the resources required to undertake such a study is high given the need for additional observers (e.g., one for the interrupter and one for the interruptee). This data collection method has been used to explore interruptions in the ICU, where a social network analysis was used to analysis the associative links created by clinical task interruptions (McCurdie, Sanderson & Aitken, 2018). The data analysis technique applied here provides insight to the complex role interruptions play within healthcare and provides a good indication that there may be more than meets the eye when exploring clinical task interruptions. For example, findings indicated the in-charge nurse experienced the most interruptions, however the Dual Perspective approach along with a social network analysis allowed for the identification of the underlying factors that led to a proportional amount of these interruptions. Therefore, interventions can potentially be focused on the root cause of interruptions (particularly those that may seem irrelevant to current role or those that manifest regularly) whilst not impeding other important healthcare processes.

Whilst the Dual Perspective Method provides an example of progress in the development of methods to explore clinical task interruptions, it does come with its limitations. As previously mentioned, many resources are required to undertake such research. For example, to generate reliability such resources are further stretched (e.g., two additional researchers would be required for inter-rater reliability). Whilst the main purpose is validation, the method may benefit from a dedicated reliability study to ensure its continued use. Furthermore, such an approach still does not provide a full understanding on how such interruptions may impact cognitive performance during specific medical tasks within the healthcare environment.

Understanding the cognitive underpinnings is another important step to understanding clinical error formation and may provide insights into task specific interventions that could potentially be easily implemented as opposed to more diverse general interventions (Cohen, Cabrera, Sisk, Welsh, Abernathy, Reeves, Wiegmann, Shappell & Boquet, 2016), however these may only be successful if they are implemented with task/environmental constraints of the healthcare setting in mind (Xiao, Rivera, Probst, Blocker, Wolf & Kellogg, 2017). Whilst there is a healthy amount of experimental research exploring various cognitive effects of task interruptions including reading comprehension (e.g., Foroughi, Werner, Barragan & Boehm-Davis, 2015), procedural/sequential memory (e.g., Altmann, Trafton & Hambrick, 2014; Li, Blandford, Cairns & Young, 2008), decision making (e.g., Trafton, Altmann, Brock & Mintz, 2003), problem solving (e.g., Hodgetts & Jones, 2006; Morgan & Patrick, 2013) and copying/recreating (Morgan et al., 2009, 2013), much of the research findings are based on performance of non-medical based tasks, but are at times generalised to a healthcare setting.

Quantitative investigation of task interruptions, despite at times being generalised to healthcare settings, have largely been focused on the disproving/supporting of theories and models through the manipulation of various constraints of task interruptions. Much of these theories on task interruptions are abstract, that is they are based upon mental concepts, therefore using abstract experimental tasks is to some extent representative in investigating the predictions of a theory in abstract terms. However abstract context does not represent concrete context, both of which may initiate different participant responses, and abstract design may be better viewed as an initial step in understanding task interruptions within a healthcare work setting. For example, the perceived consequences for making a mistake on a standardised procedural memory task may be that one loses their place in a sequence, whereas in a medical procedural task the consequences may be perceived as potential harm to a patient therefore this may encourage a different approach to the task at hand.

There is also a risk to the effectiveness of interventions proposed within healthcare settings on minimising the profound effects of task interruptions, when results on effectiveness of such interventions are informed by controlled experiments that utilise abstract tasks and do not consider other environmental constraints (Raban & Westbrook, 2014). This is also seen within the literature on other forms of interventions such as working memory training. It has been suggested that working memory training that has little ecological validity and few real-world applications can impede one's ability to transfer learnt skills to representative environments (Moreau & Conway, 2014). Likewise, interventions that reduce interference effects from task interruptions may be clear within the experimental setting, but not practically feasible to implement within a healthcare setting.

Evaluations of the healthcare literature surrounding task interruptions highlights the importance and need for continual experimental investigation, but with a better understanding of the context in which they occur. This will in turn supply a better understanding of clinical task interruptions during clinical procedures potentially informing interventions that can be generalised across contexts (McCurdie, Sanderson & Aitken, 2017). The following series of experiments draw on previous research from both the psychological and healthcare literature and proposes the use of a theoretically informed experimental design, employing a procedural memory drug administration primary task like a task used in healthcare settings.

Furthermore, the parameters of the task will be explored through interruption manipulations that mimic those that healthcare professionals are likely to experience on a regular basis including interruption complexity, frequency, mode of communication, urgency, and emotional content of interruptions. Traditional experimental tasks used to explore task interruptions have supplied useful information in understanding interruption effects, but the translation to clinical practice is still unclear. The use of more realistic yet controllable tasks will enhance the potential application of the findings, inform current theories and models of task interruptions in an applied context, and lead the way for better informed interventions to mitigate the profound effects such clinical task interruptions have. Whilst an ecologically valid controlled experimental task allows for the examination of non-observable clinical interruption characteristics, it also provides an opportunity to develop tasks under well-versed experimental paradigms, and thus interpret results in relation to task interruption (and related) theories and models.

Development of the CAMROSE Medication Pre-Administration Task and Clinical Decision-Making Task.

The CAMROSE Medication Pre-Administration Task

Given the wide range of interruptions nurses and other clinical personnel can be faced with, particularly during the medication process, it seems essential to consider the impact of clinical interruptions through this process including prior to the administration of medication. Recent work on the MfG model has explored interruption effects on well learnt procedures. The UNRAVEL task (Altmann, Trafton & Hambrick, 2014) was developed to explore the effects momentary/short task interruptions (e.g., secondary tasks taking an average of 4.4 and 2.8 s to complete). It is a procedural task where UNRAVEL is an acronym that represents each step in a sequence and one of two possible responses for that step. For example, on the first step (U), participants respond U if stimuli (e.g., letters) are underlined or I (the other possible response) if the stimuli are in italics. Hodgetts & Jones (2006) found that interruptions lasting 2.8 s can double the rate of certain procedural errors, and interruptions lasting 4.4 s tripled these errors compared to no interruption trials. These are very short interruption durations compared to other studies, with mixed effects being reported such as error rates often raising as interruption duration increases but not always significantly different to non-interruption trials (Altmann, Trafton & Hambrick, 2017).

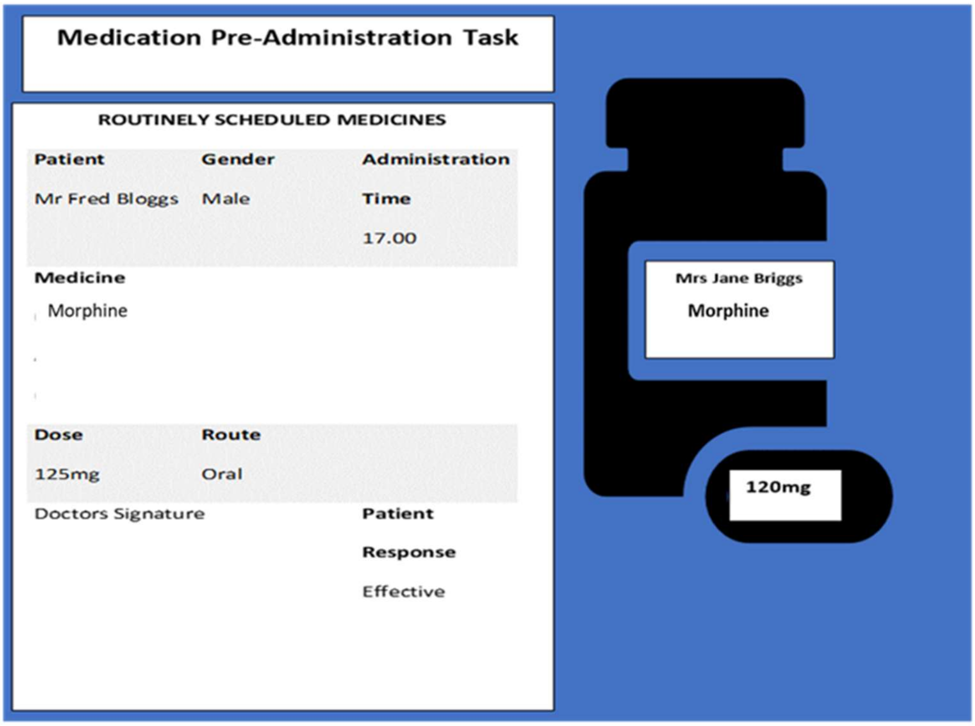
One key MfG assumption for performance on well learnt procedural tasks is that preparation for a procedural step occurs in semantic memory which then communicates with an execution process with the intention to complete the procedural step. If the communication between preparation and execution is disrupted by an interruption, errors in the procedure are more likely to arise (Trafton, Altmann & Ratwani, 2011). The task serves as a positive representation of similar procedural processes a healthcare professional may undertake when administering medication and serves as an underpinning for the development of the current experimental task CAMROSE Pre-Administration Task (detailed below). Similar procedural tasks have been used previously to explore task interruptions. For example, Li et al (2008) developed a doughnut-making task to explore the effects of task interruption on post task completion errors (errors immediately following the final step of the primary task goals). The doughnut-making task required participants to operate an interface through following several predefined steps to produce the required number of doughnuts needed. This task was further adapted by Gould, Brumby and Cox (2013) into the ‘Pharmacy Task’, so that rather than ingredients to make doughnuts, participants were given prescriptions in which the values had to be copied into five categories. Both tasks require participants to follow a strict procedural order to complete the task, and at various stages would be interrupted with a secondary task. Whilst both do move away from abstract experimental procedural tasks like UNRAVEL, it could be argued that the level of fidelity (degree of representation) in comparison to the same tasks in the real world is low. Whilst level of abstraction was not the main agender of the research in which these tasks were used, they do provide useful examples of how to implement various experimental task within an interruption paradigm. The CAMROSE task takes the experimental task development one step further. It includes a higher level of task fidelity that would represent a healthcare setting, and the interruptions were also developed with the same level of fidelity in mind. In doing so, experiments would better represent both the task in which healthcare professionals may interact with, and the interruptions they are likely to experience in turn allowing for a better exploration of errors that may occur and interventions that may mitigate them.

CAMROSE was programmed using the PsychoPy2/3 experimental builder (Peirce, Gray, Simpson, MacAskill, Hochenburger, Sogo, Kastman & Lindelov, 2019). The programming of the task took approx. 8 months to complete, which involved several iterations during its development, whilst having to also learn how to code in Python (aided by attending an additional PsychoPy course) which was required as the creation of certain task elements were outside the boundaries of the built-in builder interface. Before introducing a final version of the CAMROSE task to be used for the subsequent experiments, a pilot test with (N = 15) revealed several critical issues that first needed to be addressed.

Firstly, the initial response choice for certain steps in the CAMROSE task did not vary enough (e.g., time to administer was Early or Late, whilst patient response was Effective and Unsuccessful) resulting in certain steps having the same possible responses. This oversight resulted in difficulties in assessing where in the sequence participants were resuming and/or making errors. Therefore, re-evaluation of the CAMROSE responses was needed for the final version so that each step and possible response varied, whilst also keeping a level naturality (that is they could be viewed as the direct opposite of the other response).

Furthermore, the pilot test also revealed more technical issues with the programming that was having a significant impact on how the experiment was being ran. This included the use of video playback for the interruptions, which resulted in the slow running of the program which in-turn impacted experiment times (both the running of experiments and response recording). To overcome this issue, rather than having full videos of the interruptions, a mock-up was designed to include an image of a nurse with the associated audio playing in the background (explained in more detail below). Another issue experienced frequently was that if the version of the experiment did not coincide with the version of the experiment program installed in the labs, then numerous programming errors would occur at various point within the experiment causing a termination of the session. To overcome this issue various elements of the program had to be flexible to match the progressive development of newer program versions (future proofed). The aim of the pilot study was to test the program, and if successful then the data would be included. This was not the case, rather the pilot study was successful in finding critical confounds to the programming of the task and provided key insights into the development of the final version to be used in the proceeding experiments. Whilst this final version is the basic premise of the task, minor changes in how stimuli was presented were made across experiments which will be detailed in the corresponding methods section.

CAMROSE is an acronym that represents seven sequential steps whereby C is the first step followed by A M R O S E. Each letter of the sequence also represents one of two possible responses for that step based upon the information presented to them (Figure 1). The task uses 7 sequence steps which is like that used in the UNRAVEL task, however the nature of these steps is changed to mimic the seven recommended checks required before medication is administered. The responses to each step in the sequence are made based upon the stimuli presented to the participant.



Medication Pre-Administration Task

ROUTINELY SCHEDULED MEDICINES

Patient	**Gender**	**Administration Time**
Mr Fred Bloggs	Male	17.00
Medicine		
Morphine		
Dose	**Route**	
125mg	Oral	
Doctors Signature		**Patient Response**
		Effective

Mrs Jane Briggs

Morphine

120mg

Figure 1: Example of a standard CAMROSE interface participants engaged with.

The interface in Figure 1 represents a routine medicines schedule which mimics information that is likely to be found on a medication administration record (for example, www.awmsg.org) which includes patient details, administration time, medication class, route the medication is to be administered, doctors' signature, response to medication, and dose of medication to be administered. On the right of the interface is an image of a medication bottle displaying the patient's name, and an image of a drug capsule with the medication dose displayed. These elements are needed for the sequential steps that require checking if it is the correct patient and correct dose, as there is no physical patient/drug present to confirm who/what they are. Like the UNRAVEL task, no two responses are the same to ensure memory traces can be observed accurately and interpreted in line with the MfG model. Using the above interface in Figure 1 as an example, Table 14 highlights the following sequence that would be required in response to the interface.

Table 14 The representation of the standardised checklist, response options, and choice of rules for the CAMROSE Medication Pre-Administration Task.

Task Step	Response Options		Choice Rules	Correct response for CAMROSE task step
Step 1 = C	C	I	Is the patient's details **C**orrect or **I**ncorrect?	**I**
Step 2 = A	A	P	The time to administer the medication **A**M or **P**M?	**P**
Step 3 = M	M	D	Is the medication **M**orphine or **D**iazepam?	**M**
Step 4 = R	R	W	Is the medication dose to be administered **R**ight or **W**rong?	**W**
Step 5 = O	O	T	Is the route in which the medication needs to be administered **O**ral or **T**opical?	**O**
Step 6 = S	S	N	Has the medication to be administered been authorised and signed by a Doctor's **S**ignature or **N**o Signature	**N**
Step 7 = E	E	U	Would the patient's response to the medication be **E**ffective or **U**nsuccessful?	**E**

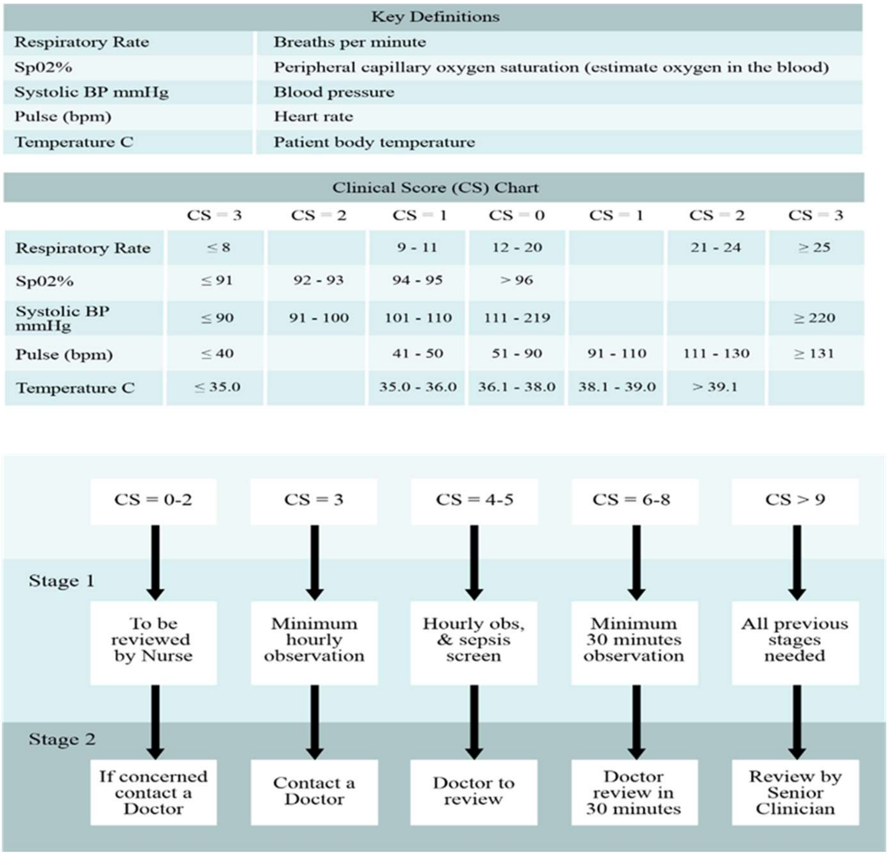
This primary task was used for the experiments described here and in the following chapters. Whilst the contextual elements on the task remained consistent throughout, some minor changes to the presentation of stimuli were made in Experiment 4, 5 and 6. These are outlined within the corresponding design sections, and adaptations were made to accommodate elements of the primary task that were believed to better represent how that task would be undertaken within the healthcare setting.

The Clinical Decision-Making Task

Whilst it is important to have a primary task that is representative of those performed in a healthcare setting, to better understand the interference effect of clinical task interruptions, such interruptions need to best match the characteristics of those likely to occur in healthcare.

To facilitate this, it was proposed the task interruption should also mimic contextual elements of the healthcare environment.

The interruption task will require participants to complete a clinical decision-making task that has been adapted from an NHS Early Warning Score (NEWS). NEWS is a tool utilised across the NHS to assess basic physiological parameters of patients and allows for the identification of potential or established critical illness (Patterson, Maclean, Bell, Mukherjee, Bryan, Woodcock & Bell, 2011). The interruption task uses a clinical score chart to measure five different physiological responses, and gives the appropriate action required based upon that score (Figure 2). The basic premise of this task is for participants to calculate a clinical score and provide the correct action required based upon an IF-THEN scenario initiated by a nurse confederate. The context of the interruption task is not only familiar to a healthcare work setting, but task elements can be manipulated in various ways. For example, complexity can be determined by the number of steps required to get a clinical score, or the way in which the nurse confederate initiates the interruption.



Key Definitions	
Respiratory Rate	Breaths per minute
Sp02%	Peripheral capillary oxygen saturation (estimate oxygen in the blood)
Systolic BP mmHg	Blood pressure
Pulse (bpm)	Heart rate
Temperature C	Patient body temperature

Clinical Score (CS) Chart

	CS = 3	CS = 2	CS = 1	CS = 0	CS = 1	CS = 2	CS = 3
Respiratory Rate	≤ 8		9 - 11	12 - 20		21 - 24	≥ 25
Sp02%	≤ 91	92 - 93	94 - 95	> 96			
Systolic BP mmHg	≤ 90	91 - 100	101 - 110	111 - 219			≥ 220
Pulse (bpm)	≤ 40		41 - 50	51 - 90	91 - 110	111 - 130	≥ 131
Temperature C	≤ 35.0		35.0 - 36.0	36.1 - 38.0	38.1 - 39.0	> 39.1	

Figure 2 Clinical score chart with key definitions and choice options for the appropriate action required.

Experiment 1: Interruption Complexity

Experimental Hypotheses

Based on the literature reviewed in relation to interruption complexity, predictions are made on both sequence and non-sequence procedural errors. First, it's predicted that sequence error rates will be higher in interruption conditions compared to a non-interruption condition, with such error rates increasing as interruption complexity increases (***H1***). The effects of interruptions during procedural tasks have been attributed to disruption in the ability to control the sequence (e.g., keep active the required sequence for the task), as opposed to performance on each step within that sequence (e.g., choosing the correct response that a given step; Trafton, Altmann & Ratwani, 2011). This is evident in the consistent reporting of no interruption effect on non-sequence errors (Altmann, Trafton & Hambrick, 2014, 2017). The same is predicted in experiment 1, in that there should be no difference in non-sequence errors between interruption and non-interruption trials (***H2***) due to interruptions disrupting the ability to control a sequence as opposed to individual step performance. Post interruption errors (e.g., errors that occurred directly after resuming the primary task) are more likely if the complexity of the interruption task leaves little room for rehearsal of primary task goals (Hodgetts, Vachon & Tremblay, 2014). It is therefore predicted that post interruption errors will increase as interruption complexity increases (***H3***). Interruptions can also have a cost on task efficiency, with interruption complexity impacting the time to resume the primary task (Monk, Trafton & Boehm-Davis, 2008), markedly so when the interrupting task increased in complexity and became more demanding (Hodgetts & Jones 2005, 2006). It is therefore predicted that the time to resume the primary task will be longer as the interruption complexity increases (***H4***).

Method

Participants

An opportunity sampling method to recruit 49 psychology students aged 18–30 years of age (M = 19.88; SD = 2.41). During the data coding process, four participants appeared to misunderstand the experimental procedure resulting in >90% inaccuracy on all dependent measures and thus their data was excluded from the main data analysis. Therefore, data was analysed and is presented for N = 45. 39 participants were female, four were male, and two did not specify gender. Participants were given course credits for their participation linked to their UG BSc Psychology degree research methods training. All participants had normal-corrected vision and hearing and were English first language or highly proficient in English as a second language.

Design

A repeated measures design was used with one main independent variable: the amount of cognitive load the clinical interruption places upon the participant, defined as the complexity associated with completing the clinical interruption task. Complexity (and thus, cognitive load) was decided by the number of steps needed to complete the secondary interrupting task, and this had four levels (Table 15).

Table 15: Examples of interruption complexity manipulations.

Interruption Complexity	Number of Steps	Example Scenario
Low	1	Patient has a pulse of 120, what is the first stage required?
Moderate	3	Patient has a pulse of 134, an Spo2% of 90, and a respiratory rate of 11, what is the second stage required?
High	5	Patient has an SpO2% of 99, a temperature of 40.1, a pulse of 101, a systolic of 225, and a respiratory rate of 22, what is the second stage required?

Task interruptions that occur within points of the experimental task where cognitive load is likely to be higher (mid-way through the sequence) may have more of a profound effect on performance than interruptions occurring at points where cognitive load is likely to be lower (at the beginning of the task; Altmann & Trafton, 2015). Given this, the interruption position was a variable controlled for in which interruptions were incorporated within the design to occur twice on each sequential CAMROSE step of the primary task throughout the experiment. Interruption position was not included in the main analysis, but outputs have been provided in the appendices. The position in which the interruption occurs was not a main variable for consideration in these experiments, and with the added limitation that there may not be an adequate sample for further breakdowns, meaningful comparisons may be limited.

Given the nature of the CAMROSE procedural primary task, several dependent variables (DV) were recorded relating to task accuracy and efficiency.

- DV-1 was sequence errors which were determined by the incorrect step performed (e.g., a step that does not logically follow on from the previous step).
- DV-2 was the non-sequence error when the correct step is performed but with the wrong response (each step has two possible responses). Both DV 1 & 2 will provide insights into task accuracy both overall and post-interruption (e.g., errors that occur directly after an interruption upon resumption of the primary task).
- DV-3 was a measure of inter-action interval (resumption lag) by recording the time taken from the end of the interruption until the first keyboard response back on the primary task (Cades et al, 2008). This will allow for the assessment of differences in disruptiveness between interruption task complexity.
- DV-4 was the reaction time on each step of the primary and interruption task. Both DV 3 & 4 timing measures allow for exploration of primary task and resumption efficiency.

Each step of the experimental task was considered as a trial (7 task steps = 7 trials), and the completion of all trials equated to 1 full sequence (7 trials = 1 full sequence). An experimental block represented a within-participant variable, and each contained 5 sequences (1 experimental block = 5 sequences = 35 trials per experimental block). With 4 experimental blocks there were a total = 140 experimental trials.

During each experimental block, each sequence was continuous until all trials were completed (e.g., E will be followed by C). At the end of each experimental block, participants were given the opportunity to take a break before beginning the next block. Interruption complexity was counterbalanced using a Latin Square (Table 16), creating 4 separate versions of the experiment to accommodate each counterbalance.

Table 16: Blocked counterbalance from interruption complexity conditions for each experimental version.

Experimental Version	Order of Interruption Experimental Block			
Version A	No Interruption	Low Complexity	Moderate Complexity	High Complexity
Version B	Low Complexity	Moderate Complexity	High Complexity	No Interruption
Version C	Moderate Complexity	High Complexity	No Interruption	Low Complexity
Version D	High Complexity	No Interruption	Low Complexity	Moderate Complexity

The same images of the routinely scheduled medicines chart occur within each experimental block, but the order of the images was randomly pre-selected using an online random sequence generator (Random.org; https://www.random.org/sequences/). Each sequential trial was interrupted twice throughout each block, equalling to 14 interruptions per experimental block, and these occurred at the end of one trial before starting the next. Interruptions occurred at the same time in each sequence (Table 17), with each sequence also being counterbalanced in each block using a Latin Square. Due to the design of experiment and how it was created, Sequence 5 remained the same in each experimental block (not counterbalanced) to ensure the block ends with a trial as opposed to an interruption.

Table 17: Within trial counterbalance for interruption position across each sequence of the experimental task.

Task Step	**Position and Sequence Interruption Occurs (N = No Interruption, Y = Interruption)**			
	Sequence 1	Sequence 2	Sequence 3	Sequence 4
C	N	Y	N	N
A	Y	N	N	Y
M	Y	Y	N	N
R	N	N	Y	N
O	N	Y	Y	N
S	N	N	N	Y
E	Y	N	Y	N

Materials

The primary and interruption task used in this experiment is the CAMROSE Medication Pre-Administration Task and Clinical Decision-Making Task explained previously were running within psychology labs on individual workstations (each separated by a partition) that held between 4-16 participants. Each workstation had a desktop PC, computer mouse and keyboard, and over-ear headphones. Throughout the experiment the headphones wear worn to reduce noise. To respond accordingly to the interruptions, participants had access to printed versions of the key definitions, clinical score chart and action sheet throughout the experiment. present at their workstation. Task interruptions were initiated by a mocked face-to-face computer interaction with a nurse confederate. When initiated the interface changed from the CAMROSE to a headshot of a confederate nurse and audio stimuli in which an IF-THEN played through headphones. Participants were required to provide the appropriate clinical score and action required based upon the scenario presented to them.

Reponses were made on the computer after the interruption and participants would press the 'enter' key on the keyboard once they were finished and returned to the primary task where they left off. Cognitive load was measured at the end of each experimental block using an electronic variation of the NASA Task Load Index (NASA-TLX; Hart & Staveland, 1988).

This was assessed on a Likert type scale (e.g., ‘How mentally demanding was the task?’, ‘How hurried or rushed was the pace of the task?’). Increments of high, medium, and low estimates for each point result in 21 gradations on the scales. The scale was programmed into the experiment so that participants could complete the scale at the end of each experimental block and would allow for the assessment of individual workload on each experimental condition.

Procedure

Upon entering the experimental room, participants were asked to read the participant information and experimental instructions before providing informed consent to participate. The experimental instructions were also explained in detail by the researcher, expressing the importance of remembering the acronym CAMROSE and its associated responses. Participants were encouraged to ask questions regarding any elements of the primary task to ensure they fully understood what was expected. After explanation of how to perform the primary task, participants completed a short practice stage without any interruptions which consisted of 14 trials. During all the practice trials, the CAMROSE acronym and its associated responses were present to help participants learn the procedure. Again, participants were encouraged to use this as much as needed throughout the practice trials. Upon completion of the practice trials for the primary task, the researcher explained the interruption task, and participants were instructed to complete the interruption task by providing a clinical score and required response based upon the if-then scenario presented, and then to return to the primary task where they had left off.

Participants were not instructed directly during the briefing that this was an interruption task but rather a secondary task in which performance on both tasks were equally important for the experiment. Participants completed another round of 14 practice trials, this time including a sample of interruptions they were expected to experience throughout the experiment phase (e.g., 1 low complexity, 2 moderate complexity, 2 high complexity). During this phase, participants were requested to wear the over-ear headphones provided until they had finished. The acronym and possible responses continued to be present for these practice trials as well. After the practice trials participants were once again encouraged to ask questions if they were unsure and/or complete another practice run if they wished to do so. If participants were happy to continue, before beginning, all paperwork not related to the experiment including the acronym was collected, and pens and phones were asked to be put away. Participants wore the headphones throughout the whole experiment. At the end of the main experimental phase, participants were fully debriefed. Total experimental time was approx. 60 minutes.

Results

Before discussing the results, it is important to highlight issues with normality found across all the experiments within this thesis. Throughout the literature there are several methods suggested to help deal with this issue and ensure the parametric assumption of normality is met before undergoing statistical testing. Firstly, one can identify potential outliers using z score analysis, with statistical outliers identified by z scores > 3.29. This was performed, and whilst outliers were identified within some conditions (but were never consistent across all conditions for any participant), removing them or replacing their values with the grand mean did not have any significant impact on the normality of the data or the outcome. All conditions were also transformed using a Square-Root method (New Variable = SQRT (Old Variable)), as conditions appeared to be moderately positively skewed (Tabachnick & Fidell, 2007). Whilst this made the distribution on some variables normal, for others it had the opposite effect (e.g., the control condition appeared to be platykurtic after transformation).

Furthermore, after running analysis with these transformations the same outcome was found with no effect on the statistical power of results. Furthermore, an alternative non-parametric statistical test was performed which revealed the same outcome. With this in mind, and having statistical power above the recommended expectation of $\beta > .8$ across most of the main variables (an exception made for non-sequence errors and interruption position where these will be discussed further in the discussion) that does not seem to be effected by the above methods, and the frequency tables indicate a close normality of data (at face value before statistical normality checks), some literature suggest that multivariate tests (such as Analyse of Variance) are robust to such deviations (Bryman & Cramer, 1997; Pituch & Stevens, 2016). Given this, all experiments will use the appropriate parametric tests, however caution will be given to interpretation of results given the normality issues experienced but will also consider other possible reasons for this beyond the participant sample (e.g., novelty of task, number of experimental trials performed).

The nature or the experimental paradigm allows for various levels of analysis to be considered. The order of analysis presented below (and for the preceding experiments) will consist of the following:

- General analysis of interruption effects on performance with a specific focus on sequence errors, non-sequence errors, and inter-action interval.

- Individual task step analysis keeping the focus on the same dependent variables, but also considering post-interruption performance.

Given the number of analyses performed, and various levels of repeated measures with each of these analyses, sphericity assumptions are at times violated to various degrees. In order to both reduce the risk of Type I/II errors being made, when such violations are reported and the appropriate correction to the results will be applied using the following rules:

- When no violations are found results will reflect sphericity assumed.
- If significant violation of sphericity is found, and Grennhouse-Geisser > 0.75, Huynh-Feldt will be reported. Due to the natural increase in p value to compensate for corrections, it has been suggested that Greenhoues-Geisser is too conservative and therefore may increase the risk of a false negative being reported (e.g., increase beyond significant, whilst there are still significant differences within post-hoc analysis).
- However, if Greenhouse-Geisser is < 0.75, then findings will be reported using the this more conservative adjustment (Abdi, 2010; Field, 1998).

Complexity Analysis 1 - General effects of interruption complexity on sequence errors during CAMROSE Medication Pre-Administration Task.

A repeated measure analysis of variance (ANOVA) was used to test the effects of interruption complexity (No Interruption, Low Complexity, Moderate Complexity, High Complexity) on the number of sequence errors made. Results indicated a significant effect of interruptions on the number of sequence errors being made, F(3, 132) = 8.467, MSE = 8.75, $p < .001$, $\eta 2p = .161$, with participants making significantly less sequence errors in the no interruption condition (M = 2.13, SD = 3.22) compared to the low (M = 4.44, SD = 4.56), moderate (M = 4.68, SD = 4.80), and high (M = 4.88, SD = 4.86) complexity conditions with all p's < .001. There was no significant difference in the number of sequence errors being made between the low, moderate, and high complexity conditions with all p's > .05, despite there being a visible trend in that as complexity is increased so is the number of sequence errors being made (Figure 2).

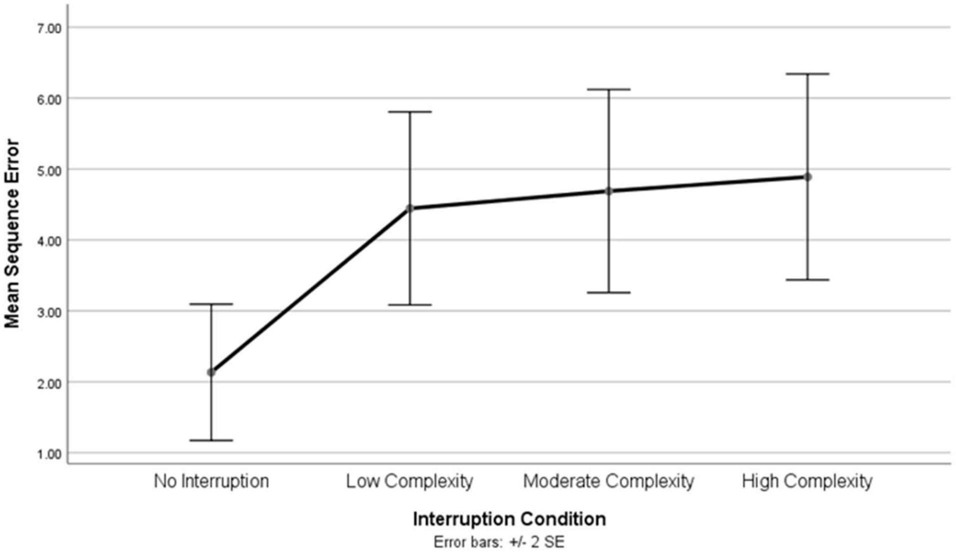


Figure 3 Mean sequence error across interruption complexity conditions.

Complexity Analysis 2 - Comparison of post-interruption sequence errors (errors occurring directly after the interruption upon resumption of primary task) compared to no interruption (control) sequence errors.

The same repeated measure ANOVA was used to explore whether the number of sequence errors significantly increased/decreased directly after resuming a primary task (post-interruption errors) across each complexity manipulation compared to the errors observed in the control condition. Results indicated a significant effect of complexity on the number of post-interruption sequence errors being made, F(2.421, 106.52) = 2.972, MSE = 5.23, p = .046, η2p = .063. However, even with the appearance of a small trend emerging (Figure 9) pairwise comparisons using Bonferroni post-hoc analysis did not reveal significant differences on post-interruption sequence errors between the No Interruption (M = 2.13, SD = 3.22), Low Complexity (M = 3.11, SD 3.54), Moderate Complexity (M = 3.13, SD = 3.50), and High Complexity (M = 3.28, SD = 3.25) conditions.

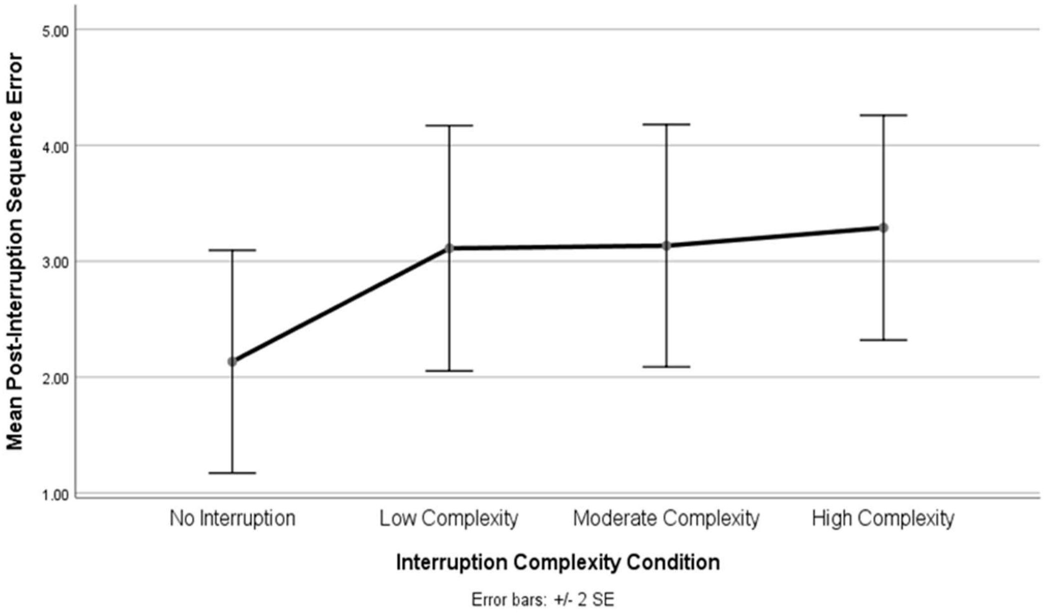


Figure 4 Mean post interruption sequence error across interruption complexity conditions.

Complexity Analysis 3 - General effect of interruption complexity, CAMROSE task step, and the interaction of both on sequence errors.

A 4 (Interruption Complexity: No Interruption, Low Complexity, Moderate Complexity, High Complexity) x 7 (CAMROSE Task Step: Step 1 (C), Step 2 (A), Step 3 (M), Step 4 (R), Step 5 (O), Step 6 (S), Step 7 (E)) repeated measures ANOVA was used to explore the main effect of interruption complexity and CAMROSE task step as well as the interacting effect on sequence errors (Figure 10). Results indicates a significant main effect of interruption complexity on the number of sequence errors made on a CAMROSE task step F(3, 132) = 8.640, MSE = 1.254, p < .001, η2p = .164. Pairwise comparisons using Bonferroni post-hoc analysis revealed a similar trend in comparative analyses in that significantly less sequence errors were made on a task step in the No Interruption condition (M = .305, SD = .460) compared to the Low Complexity (M = .641, SD = .664, p <.001), Moderate Complexity (M = .670, SD = .686, p <.001), and High Complexity conditions (M = .705, SD = .706, p <.01), but there was no significant difference between any of the other conditions on the number of sequence errors made on task steps (p’s >.05). There was a significant main effect of CAMROSE task step on the number of sequence errors, F(2.84, 124.96) = 6.032, MSE = 5.12, p < .01, η2p = .121. Pairwise comparisons using Bonferroni post-hoc analysis revealed that more sequence errors were being made on Step 2 (A) (M = 1.17, SD = 1.46) compared to Step 1 (C) (M = .422, SD = .383), Step 3 (M) (M = .522, SD = 1.15), Step 4 (R) (M = .694, SD = 1.02), Step 5 (O) (M = .450, SD = .599), Step 6 (S) (M = .344, SD = .316), and Step 7 (E) (M = .450, SD = .638) with all p’s <.05. There was no significant difference between any of the other CAMROSE task steps on the number of sequence errors being made with all p’s >.05. There was no significant interaction between interruption complexity and CAMROSE task step on the number of sequence errors being made, F(5.64, 248.28) = 1.106, MSE = 2.98, p = .359, η2p = .025.

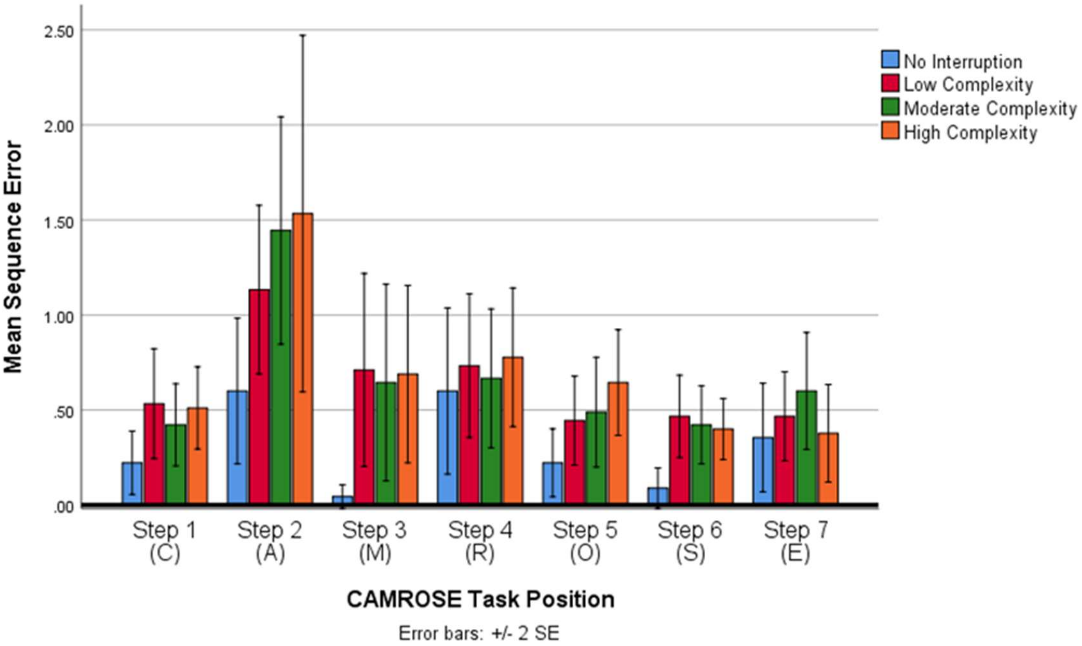


Figure 5 Sequence errors across each CAMROSE task step for each interruption complexity condition.

Complexity Analysis 4 - Comparison of post-interruption sequence errors (errors occurring directly after the interruption upon resumption of primary task) compared to no interruption (control) sequence errors through comparison of interruption complexity, CAMROSE task step, and the interaction of both.

The following analysis considers the effect the interruptions varying in complexity on the performance when they occur at a task point.

A 4 (Interruption Complexity: No Interruption, Low Complexity, Moderate Complexity, High Complexity) x 7 (CAMROSE Task Step: Step 1 (C), Step 2 (A), Step 3 (M), Step 4 (R), Step 5 (O), Step 6 (S), Step 7 (E)) repeated measures ANOVA was used to explore the main effect of interruption complexity and CAMROSE task step as well as the interacting effect on post-interruption sequence errors (Figure 6). A partially significant main effect interruption complexity on the number of post-interruption sequence errors made on a CAMROSE task step F(2.42, 106.52) = 2.97, MSE = .748, p = .046, η2p = .063. Whilst there is a small liner trend emerging in that as interruption complexity increases the average number of post-interruption sequence errors made on a CAMROSE step also increased Bonferroni pairwise comparisons indicate no significant difference in these trends (p’s >.05) ; No Interruption condition (M = .305, SD = .460), Low Complexity (M = .444, SD = .507), Moderate Complexity (M = .447, SD = .501) and High Complexity conditions (M = .469, SD = .464). There was a partially non-significant effect of CAMROSE step on the number of post-interruption sequence errors, F(3.61, 159.21) = 2.27, MSE = .608, p = .07, η2p = .049.

There was a partially significant interaction between interruption complexity and CAMROSE task position on the number of post-interruption sequence errors F(5.86, 258.14) = 2.18, MSE = 1.13, p = .046, η2p = .047. Bonferroni post-hoc analysis revealed that less sequence errors were made when they occurred at CAMROSE step 3 (M) in the No Interruption condition (M = .044) compared to post-interruption sequence errors interruptions on the same position when interruptions were either Low Complexity (M = .378, p = .011), Moderate Complexity (M = .333, p = .032), or High Complexity (M = .622, p <.001). Furthermore, less sequence errors were also made when they occurred at CAMROSE step 6 (S) in the No Interruption condition (M = .089) compared to post-interruption sequence errors interruptions on the same position when interruptions were either Low Complexity (M = .422, p = .017), Moderate Complexity (M = .422, p = .017), or High Complexity (M = .533, p <.01). No other interaction effects were found with all other p’s >.05.

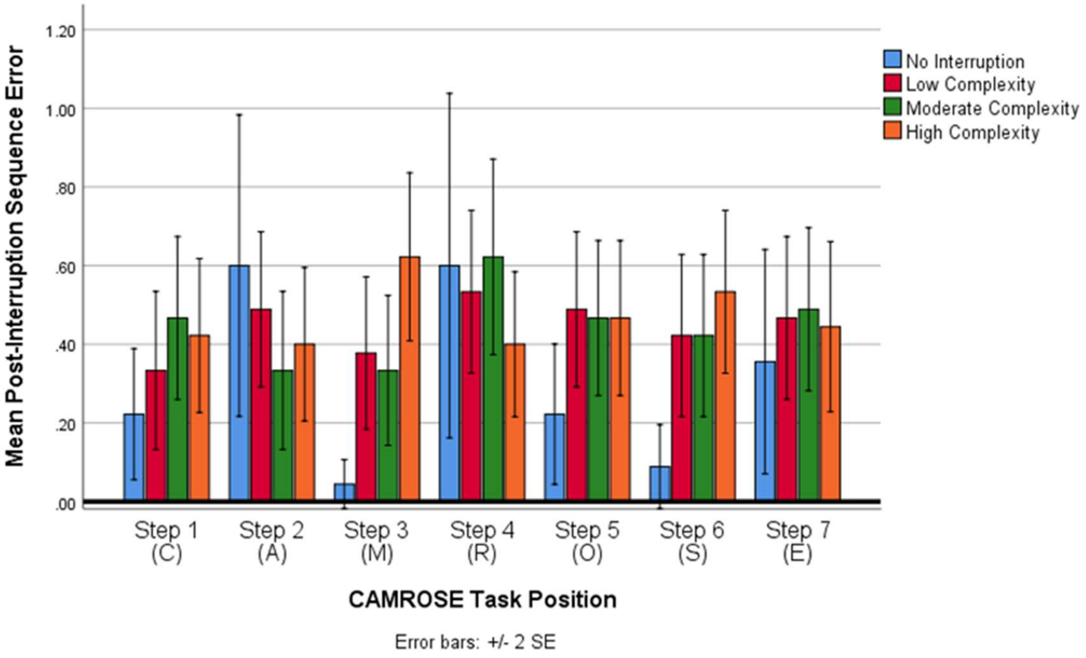


Figure 6 Post interruption sequence errors across each CAMROSE task step for each interruption complexity condition.

Complexity Analysis 5 - General effects of interruption complexity on non-sequence errors during CAMROSE Medication Pre-Administration Task

A repeated measure analysis of variance (ANOVA) was used to test the effects of interruption complexity (No Interruption, Low Complexity, Moderate Complexity, High Complexity) on the number of non-sequence errors made. Results indicated there was no significant effect of interruptions on the number of non-sequence errors being made across interruption complexity condition, F(3, 132) = .996, MSE = .987, p = .397, η2p = .022. Despite such finding there did appear to be some unusual trends in the data (Figure 7), with the most non-sequence errors occurring in the Moderate Condition (M = 1.00, SD = 1.47) but yet the least appear in the High Complexity condition (M = .644, SD = .980) even in comparison to the No Interruption (M = .844, SD = 1.52) and Low Complexity condition (M = .777, SD = 1.20).

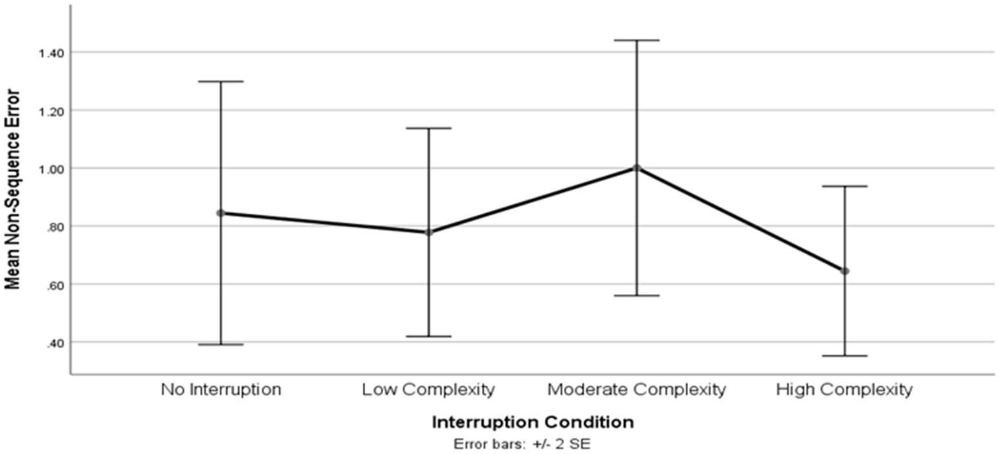


Figure 7 Mean non-sequence errors across interruption complexity conditions.

Complexity Analysis 6 - Comparison of post-interruption non-sequence errors (errors occurring directly after the interruption upon resumption of primary task) compared to no interruption (control) non-sequence errors.

A repeated measure ANOVA was used to explore whether the number of non-sequence errors significantly increased/decreased directly after resuming a primary task (post-interruption errors) across each complexity manipulation compared to the non-sequence errors observed in the control condition. There was significant effect of interruption complexity on the number of non-sequence errors, F(2.06, 90.68) = 5.30, MSE = .915, p <.01, η2p = .108. Bonferroni pairwise comparisons reveal that significantly less non-sequence post interruption errors were made in the Low Complexity (M = .244, SD = .484) condition compared to non-sequence errors in the No Interruption condition (M = .844, SD = 1.52, p = .017), with no significant difference in comparison to the Moderate (M = .555, SD = .989) and High (M = .311, SD = .596, p’s >.05) complexity conditions despite participants making more post-interruption non-sequence errors (although still less compared the No Interruption condition; Figure 8).

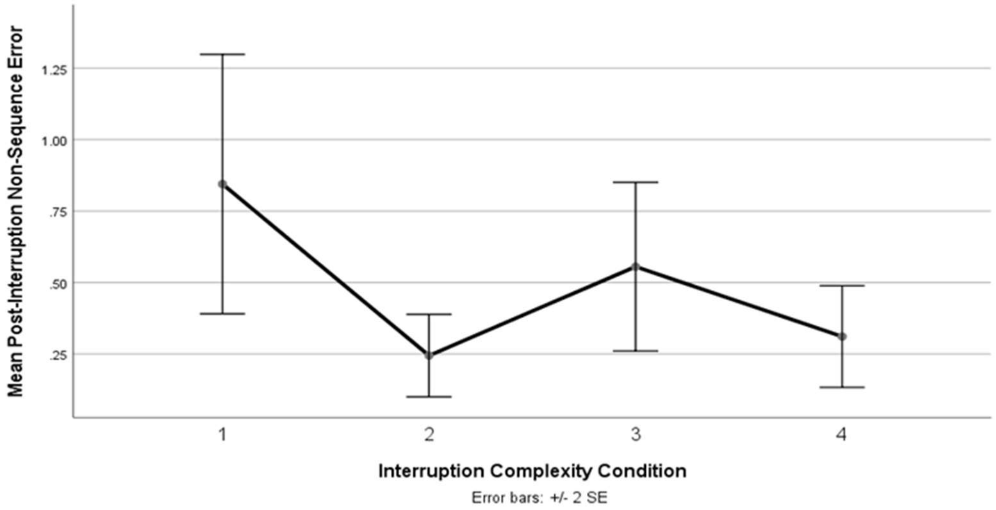


Figure 8 Post interruption non-sequence error across interruption complexity conditions.

Complexity Analysis 7 - General effect of interruption complexity, CAMROSE task step, and the interaction of both on non-sequence errors.

A 4 (Interruption Complexity: No Interruption, Low Complexity, Moderate Complexity, High Complexity) x 7 (CAMROSE Task Step: Step 1 (C), Step 2 (A), Step 3 (M), Step 4 (R), Step 5 (O), Step 6 (S), Step 7 (E)) repeated measures ANOVA was used to explore the main effect of interruption complexity and CAMROSE task step as well as the interacting effect on non-sequence errors (Figure 10). There was no significant main effect of complexity on the number of non-sequence errors being made on each task step, F(3, 132) = .877, MSE = .141, p = .45, η2p = .020. There was a significant main effect of CAMROSE task step on the number of non-sequence errors being made, F(2.67, 117.64) = 5.92, MSE = .923, p = <.01, η2p = .119. Bonferroni pairwise comparisons revealed that significantly more non-sequence errors were made on CAMROSE task step 1 (M = .322, SD = .570) compared to CAMROSE task step 3 (M = .005, SD = .037, p = .012), and CAMROSE task step 5 (M = .011, SD = .052, p = .017). There were no other significant differences in the number of non-sequence errors being made on any other CAMROSE task step with all p's >.05. There was no significant interaction between interruption complexity and CAMROSE task step on the number of non-sequence errors being made, F(5.75, 253.28) = .470, MSE = .430, p >.05, η2p = .011.

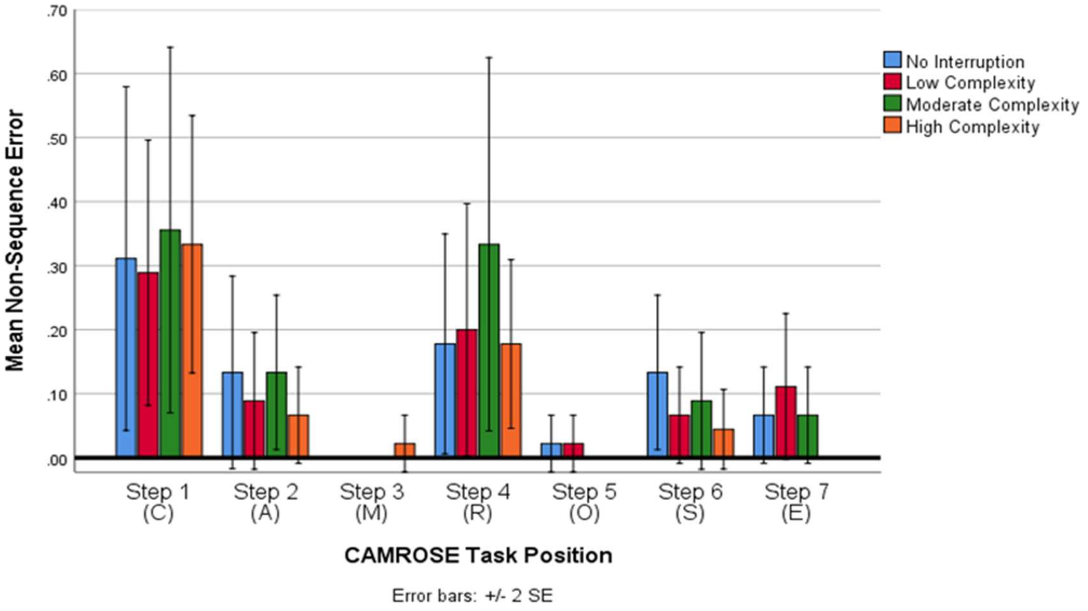


Figure 9 Post interruption non-sequence errors across each CAMROSE task step for each interruption complexity condition.

Complexity Analysis 8 - Comparison of post-interruption non-sequence errors (errors occurring directly after the interruption upon resumption of primary task) compared to no interruption (control) sequence errors through comparison of interruption complexity, CAMROSE task step, and the interaction of both.

A 4 (Interruption Complexity: No Interruption, Low Complexity, Moderate Complexity, High Complexity) x 7 (CAMROSE Task Step: Step 1 (C), Step 2 (A), Step 3 (M), Step 4 (R), Step 5 (O), Step 6 (S), Step 7 (E)) repeated measures ANOVA was used to explore the main effect of interruption complexity and CAMROSE task step as well as the interacting effect on post-interruption non-sequence errors. A significant main effect was revealed on interruption complexity on the number of post-interruption non-sequence errors made on a CAMROSE task step F(2.06, 90.68) = 5.30, MSE = .131, $p < .01$, η2p = .108. Bonferroni pairwise comparisons indicate that more non-sequence errors were being made in the No Interruption condition (M =.121, SD = .191) compared to post-interruption non-sequence errors in the Low Complexity condition (M = .035, SD = .069). There was no other significant difference with all p's >.05. There was no significant main effect of CAMROSE task step on the number of post-interruption non-sequence errors being made, F(4.13, 181.91) = 2.06, MSE = .133, $p > .05$, η2p = .045. There was also no significant interaction between interruption complexity and CAMROSE task step on the number on post-interruption non-sequence errors being made F(4.74, 208,56) = 1.81, MSE = .362, $p > .05$, η2p = .040.

Complexity Analysis 9 - General comparison of inter-action interval (time between to respond to each CAMROSE task step) across each interruption complexity condition.

A repeated measure analysis of variance (ANOVA) was used to test the effects of interruption complexity (No Interruption, Low Complexity, Moderate Complexity, High Complexity) on the average time (seconds) to make a response on a task step (inter-action interval). There was a significant effect of interruption complexity on the inter-action interval, F(2.37, 104.44) = 7.57, MSE = 1.09, $p < .001$, η2p = .147. Bonferroni pairwise comparisons revealed that participants were taking significantly longer to make a response in the Low Complexity (M = 3.03, SD = 1.33), Moderate Complexity (M = 3.01, SD = 1.26) and High Complexity (M = 3.38, SD = 1.46) conditions compared to the No Interruption condition (M = 2.46, SD = 1.09) with all p's >.05 (Figure 10).

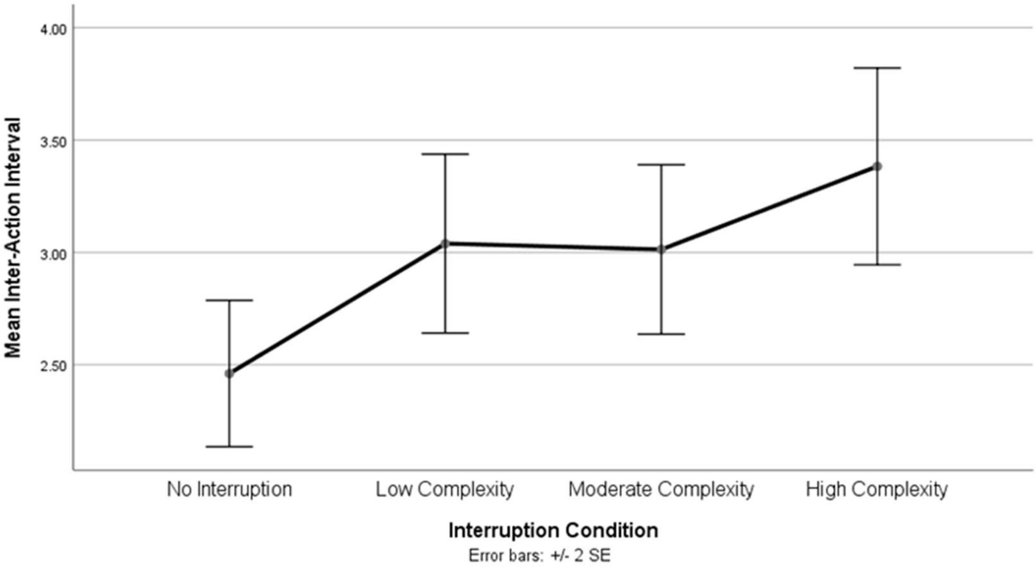


Figure 10 Comparison of inter-action interval across interruption complexity

Complexity Analysis 10 - Comparison of post-interruption resumption lag (time between end of interruption and first response back onto primary task) compared to inter-action interval.

Paired samples t-tests were used to test for differences between resumption lag and inter-action interval on each complexity manipulation. Results indicated that resumption lag was significantly higher (M = 4.02, SD = 2.09) than inter-action interval (M = 3.03, SD = 1.33) in the Low Complexity condition t(44) = 6.79, p <.001, significantly higher (M = 3.93, SD = 2.04) than inter-action interval (M = 3.01, SD = 1.26) in the Moderate Complexity condition t(44) = 6.05, p <.001, and significantly higher (M = 4.62, SD = 2.35) than inter-action interval (M = 3.38, SD = 1.46) in the High Complexity condition t(44) = 7.54, p <.001 (Figure 11).

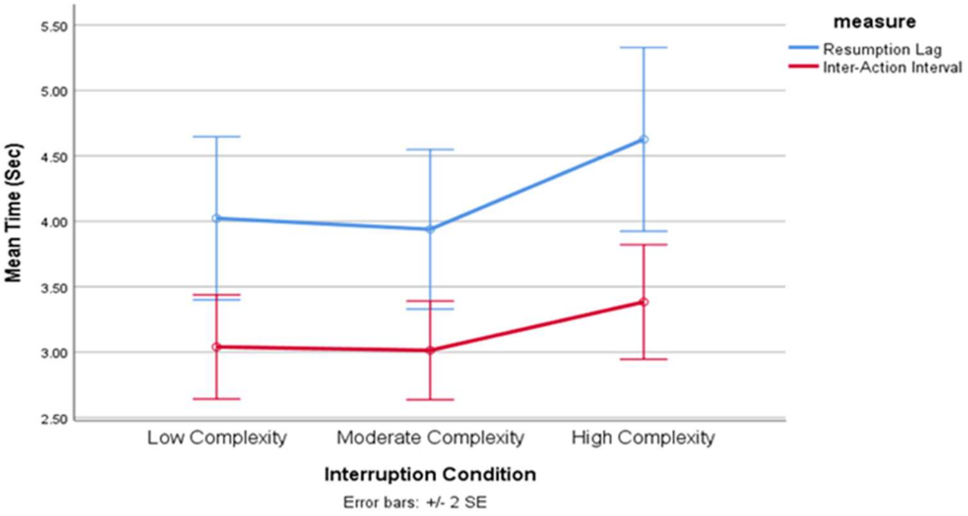


Figure 11 Comparison of inter-action interval and resumption lag across interruption complexity

Complexity Analysis 11 - Comparison of resumption lag compared to no interruption (control) inter-action interval across interruption complexity, CAMROSE task step, and the interaction of both.

A 4 (Interruption Complexity: No Interruption, Low Complexity, Moderate Complexity, High Complexity) x 7 (CAMROSE Task Step: Step 1 (C), Step 2 (A), Step 3 (M), Step 4 (R), Step 5 (O), Step 6 (S), Step 7 (E)) repeated measures ANOVA was used to explore the main effect of interruption complexity and CAMROSE task step as well as the interacting effect on resumption lag (Figure 17). A significant main effect was found on interruption complexity step F(3, 132) = 20.99, MSE = 4.78, $p < .001$, $\eta 2p = .323$. Bonferroni pairwise comparisons indicated that it took longer to resume a task step after an interruption in the Low Complexity (M = 4.37, SD = 2.41), Moderate Complexity (M = 4.26, SD = 2.14) and High Complexity (M = 4.99, SD = 2.39) conditions compared to the average time to complete the same task step in the No Interruption condition (M = 2.46, SD = 1.09) with all p's <.001. There was no significant main effect of task step on the time to resume a task after an interruption F(4.33, 190.76) = .718, MSE = 9.21, $p > .05$, $\eta 2p = .016$, and no significant interaction between interruption complexity and CAMROSE task step on resumption time F(5.85, 257.47) = 1.93, MSE = 18.30, $p > .05$, $\eta 2p = .042$.

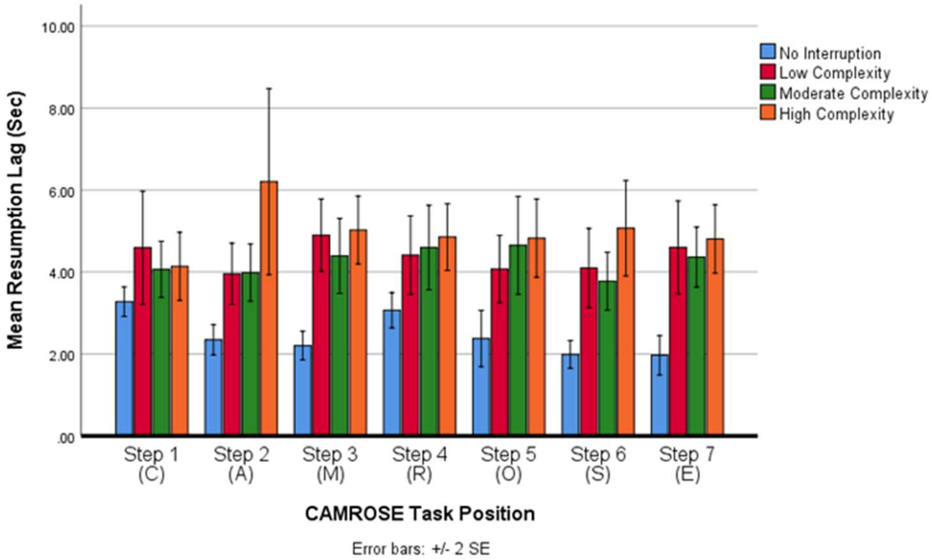


Figure 12 Resumption lag across each CAMROSE task step for each interruption complexity condition.

Summary

Task interruptions had a significant effect on the number of sequence errors being made compared to the no interruption condition. However, despite a trend in that as complexity increased so did the number of sequence errors, these were not significantly different. This only partially supports predictions made on sequence errors. There were no significant differences of task interruptions on the number of non-sequence errors being made supporting hypothesis two. Within each interruption complexity condition, the time to resume the primary task after an interruption was significantly longer when compared to the inter-action interval. Such resumption times increased further as complexity increased and indicates that the interruptions may differ in the cognitive load they place upon the individual.

There was only a partially significant difference in the number of post-interruption sequence errors being made compared to the no interruption condition. Whilst a similar trend is present in that as complexity increases so does the number of sequence errors, post hoc analysis did not reveal any significant differences. This may be due to the use of a more conservative post hoc analysis.

Taken together, there are both similarities and differences in the outcomes explored in this experiment compared to those previously reported in the literature. Firstly, it is evident that interruptions impact performance, both in terms of accuracy and efficiency. However, interruptions within this experiment only had to occur for the significant effects to be observed, with such effects not significantly varying in terms of complexity. Contrary to what was hypothesised, in terms of higher complexity interruptions placing higher cognitive burden on individuals leaving less resources for recall, it appears that this was the case regardless of the level of complexity. One possible explanation could be that the contextual elements of the task left little room for rehearsal of the suspended task goals. If the interruption is perceived as a complex task, then varying complexity in terms of the number of steps may have little impact, as it's still complex. This effect may also be mediated by the participation sample, who were not healthcare professionals. However, this could be interpreted as evidence in support of the role of context on performance, that is, if the context did not influence performance, then the manipulation of complexity could potentially be more evident (e.g., Radovic & Manzey, 2022). Whilst this cannot be conclusively supported, consideration should be given to the visible trends in the data to minimise the risk of Type 1 & 2 errors being made. Because of the trends but no significant difference, it may be attributed to the variance within the sample. Or it may be that other interruption factors (e.g., frequency, modality etc) have a more prominent effect within boundaries of the experimental task being used.

Experiment 2: Interruption Frequency

Experimental Hypotheses

Given the interrupt-driven nature of a healthcare setting, in which efficient communication between many interdisciplinary work systems is sometimes dependent on interruptions to ensure patient safety, it is not surprising that interrupts are frequently characterised as frequent. According to research, frequent interruptions might have a significant impact on individual decision-making performance (Speier, Valacich & Vessey, 1999). Whilst this study was particularly focused on decision-making performance, Monk (2004) took more of a focus on how interruption frequency may impact primary task resumption and resumption error (errors that occur immediately after the interruption). Results showed that frequent interruptions surprisingly improved primary task resumption after an interruption and resumption error rates decreased. These findings indicate that people can adapt to the fast-paced nature of the interruption task. If this were always the case, however, it would be less of an issue that disruptions in healthcare settings with highly qualified healthcare staff had less of an impact than is commonly stated. In healthcare settings, interruptions can easily become as important as the original activity, and it might take a considerable amount of time to get back to it once it has been put on hold (e.g., Brixey et al, 2008; Westbrook, Ampt, Kearney & Rob, 2008).

Based upon the literature reviewed, it is hypothesised that there will be a greater number of sequence errors in conditions where there is a higher frequency of interruptions in comparison to the case where there is no interruption and that the number of errors will grow as the frequency of the interruptions grows (H1). In terms of non-sequence errors, there will be no difference between having a high frequency of interruptions and not having any interruptions at all (H2). This is because interruptions disrupt the ability to control a sequence, as opposed to the performance of individual steps. The time it takes to resume the primary task after an interruption will be longer than the average time it takes to make a response; however, the time it takes to resume the primary task will decrease as the frequency of the interruptions increases (H3). Finally, when interruptions occur less frequently, the likelihood of post-interruption errors occurring is lower. However, when interruptions occur more frequently, the likelihood of post-interruption errors occurring increases (H4).

Method

Participants

An opportunity sampling method was used to recruit 42 psychology students aged 18-31 years old (M = 19.70; SD = 2.07). During the data coding process, two participants appeared to misunderstand the experimental procedure, resulting in >90% inaccuracy on all dependent measures, and their data were thus excluded from the main data analysis. As a result, data for N = 40 were analysed and presented. Six men and 34 women took part in the study. Participants were given course credits for their participation as part of their UG BSc Psychology degree research methods training. All participants had normal-corrected vision and hearing and spoke English as a first or second language.

Design

The study used a repeated measures design with one main independent variable: the percentage of trials interrupted, which was defined as the frequency of clinical task interruptions. The number of interruptions within an experimental block determined frequency, which had four levels: Low Frequency = 7 Interruptions (20% of trials), Moderate Frequency = 14 Interruptions (40% of trials), High Frequency = 21 Interruptions (60% of trials). Furthermore, interruptions that occur at points in the experimental task where the cognitive load is likely to be higher (middle of the sequence) may have a greater impact on performance than interruptions that occur at points where the cognitive load is likely to be lower (at the beginning of the task; Altmann & Trafton, 2015). Given this, interruption position was a controlled variable, with interruptions occurring at least twice on each sequential step of the primary task (CAMROSE) throughout the experiment. As defined in experiment one, all interruptions were considered low in complexity.

The same dependent variables (DV) will be examined in this experiment as they were in the previous one. Therefore DV-1 was a sequence error which was determined by the incorrect step performed (e.g., a step that does not logically follow from the previous step). Non-sequence errors occur when the correct step is performed but with the incorrect response (each step has two possible responses). Both DVs will provide information about task accuracy overall and post-interrupt (e.g., errors that occur directly after an interruption upon resumption of the primary task). To assess the task and resumption efficiency, timing measures (such as time to resume the primary task - resumption lag) were also collected. DV-3 was a measure of inter-action interval (resumption lag) that measured the time between the end of an interruption and the first keyboard response back on the primary task (Cades et al, 2008). This will allow for a comparison of the disruptiveness of interruption task complexity. The reaction time on each step of the primary and interruption tasks was DV-4. The cognitive workload was assessed to assess participants perceived cognitive workload on each experimental condition and to help validate each variance in each condition.

Each step of the experimental task was treated as a trial (7 trials = 1 full sequence), and an experimental block was made up of 5 sequences (1 block = 5 sequences = 35 trials). Each block represented a frequency level within a participant, for a total of four blocks (140 trials). Each sequence was continuous during each experimental block until all trials were completed (e.g., E was followed by C). Participants were given the option to take a break at the end of each experimental block before moving on to the next. To ensure that the interruptions are equal in complexity, each will require only one step to complete. While the interruption frequency conditions were balanced, it was not possible to balance the sequences as in the first experiment due to the high number of interruptions that occurred. The frequency of interruptions was thus counterbalanced using the same Latin Square as in experiment 1, yielding four versions of the experiment. Within each experimental block, the same images of the routinely scheduled medicines chart appeared, but the order of the images was pre-selected at random using an online random sequence generator (Random.org; https://www.random.org/sequences/).

The location of the interruptions varied depending on the frequency condition. Interruptions occurred simultaneously throughout each sequence and position in the Low-Frequency condition. Interruptions occurred in the Moderate Frequency condition in a manner similar to those observed in experiment 1, with interruptions occurring at least twice throughout each sequence and twice in each position. Interruptions occurred at least three times on each sequence and across each position in the High-Frequency condition.

Materials

The primary and interruption task used in this experiment is the CAMROSE Medication Pre-Administration Task and Clinical Decision-Making Task explained in Section 4.2.1/4.2.2. Experiments were running within psychology laps on induvial workstations (each separated by a partition) that held between 4-16 participants. Each workstation had a desktop PC, computer mouse and keyboard, and over-ear headphones. To respond accordingly to the interruptions, participants had a paper reference version of the clinical score chart and actions required present at their workstation. Interruptions were initiated by an image of a nurse and audio recording of a clinical If-Then scenario. Reponses were made on the computer after the interruption and participants would press the 'enter' key on the keyboard once they were finished and returned to the primary task where they left off. Cognitive load was measured at the end of each experimental block using an electronic variation of the NASA Task Load Index (NASA-TLX; Hart & Staveland, 1988). This was assessed on a Likert type scale (e.g., 'How mentally demanding was the task?', 'How hurried or rushed was the pace of the task?'). Increments of high, medium, and low estimates for each point result in 21 gradations on the scales. The scale was programmed into the experiment so that participants could complete the scale at the end of each experimental block and would allow for the assessment of individual workload on each experimental condition.

Procedure

Upon entering the experimental room, participants were asked to read the participant information and experimental instructions before providing informed consent to participate. The experimental instructions were also explained in detail by the researcher, expressing the importance of remembering the acronym CAMROSE and its associated responses. Participants were encouraged to ask questions regarding any elements of the primary task to ensure they fully understood what was expected. After explanation of how to perform the primary task, participants completed a short practice stage without any interruptions which consisted of 14 trials. During all the practice trials, the CAMROSE acronym and its associated responses were present to help participants learn the procedure. Again, participants were encouraged to use this as much as needed throughout the practice trials. Upon completion of the practice trials for the primary task, the researcher explained the interruption task, and participants were instructed to complete the interruption task by providing a clinical score and required response based upon the if-then scenario presented, and then to return to the primary task where they had left off.

Participants were not instructed directly during the briefing that this was an interruption task but rather a secondary task in which performance on both tasks were equally important for the experiment. Participants completed another round of 14 practice trials, this time including a sample of interruptions they were expected to experience throughout the experiment phase. During this phase, participants were requested to wear the over-ear headphones provided until they had finished. The acronym and possible responses continued to be present for these practice trials as well. After the practice trials participants were once again encouraged to ask questions if they were unsure and/or complete another practice run if they wished to do so. If participants were happy to continue, before beginning, all paperwork not related to the experiment including the acronym was collected, and pens and phones were asked to be put away. Participants wore the headphones throughout the whole experiment. At the end of the main experimental phase, participants were fully debriefed. Total experimental time was approx. 60 minutes.

Results

Frequency Analysis 1 - General effects of interruption frequency on sequence errors during CAMROSE Medication Pre-Administration Task.

A repeated measure analysis of variance (ANOVA) was used to test the effects of interruption frequency (No Interruption, Low Frequency, Moderate Frequency, High Frequency) on the number of sequence errors made. Results indicated a significant effect of interruption frequency on the number of sequence errors being made, *F*(1.85, 72.36) = 4.57, MSE = 9.59, *p* = .016, $\eta^2_p = .105$. Whilst there was an observable trend (Figure 18) in that as interruption frequency increased so did the number of sequence errors. Bonferroni pairwise comparisons revealed a partially non-significant difference between the No Interruption (M = 1.47, SD = 2.37) and High Frequency (M = 3.47, SD = 5.50, p = .072) conditions with all other p's >.05.

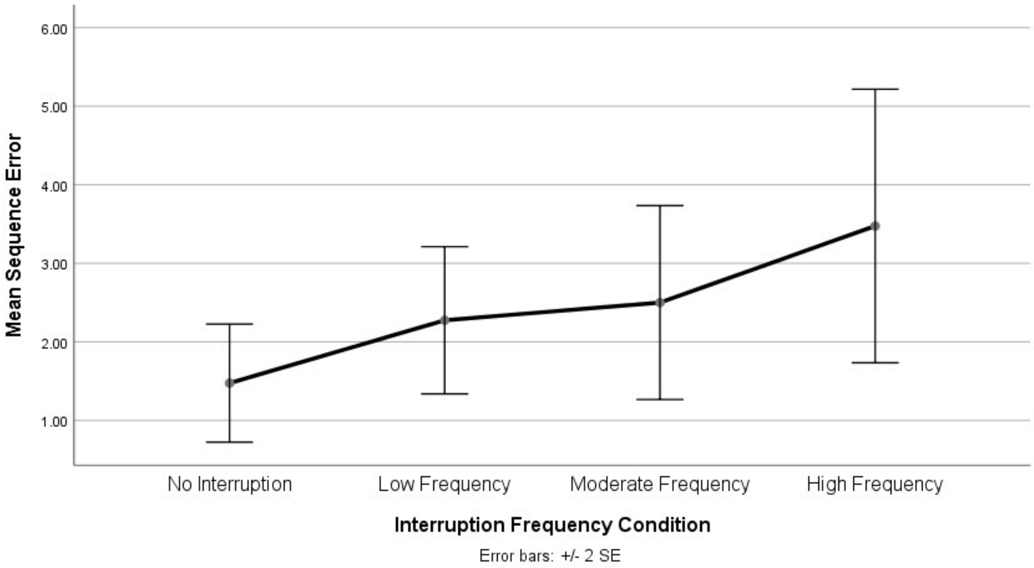


Figure 13 Mean sequence error across interruption frequency conditions.

Frequency Analysis 2 - Comparison of post-interruption sequence errors (errors occurring directly after the interruption upon resumption of primary task) across interruption frequency manipulations compared to no interruption (control) sequence errors.

A repeated measure ANOVA was used to explore whether the number of sequence errors significantly increased/decreased directly after resuming a primary task (post-interruption errors) across each frequency manipulation compared to the errors observed in the control condition. Results indicated a significant effect of frequency on the number of post-interruption sequence errors being made, *F*(1.75, 68.46) = 4.71, MSE = 6.89, *p* = .015, η^2_p = .108. Pairwise comparisons using Bonferroni post-hoc analysis revealed that whilst not significant with *p's* <.05, less post-interruption sequence errors were made in the Low Frequency (*M* = 1.20, *SD* = 1.77) and Moderate Frequency (*M* = 1.42, *SD* = 2.36) conditions, but more post-interruption sequence errors in the High Frequency condition (*M* = 2.72, *SD* = 4.69) compared to sequence errors made in the No Interruption condition (*M* = 1.47, *SD* = 2.37). There was a significant increase in the number of post-interruption errors made in the High Frequency condition compared to the Low and Moderate Frequency conditions with *p's* <.05 (Figure 14).

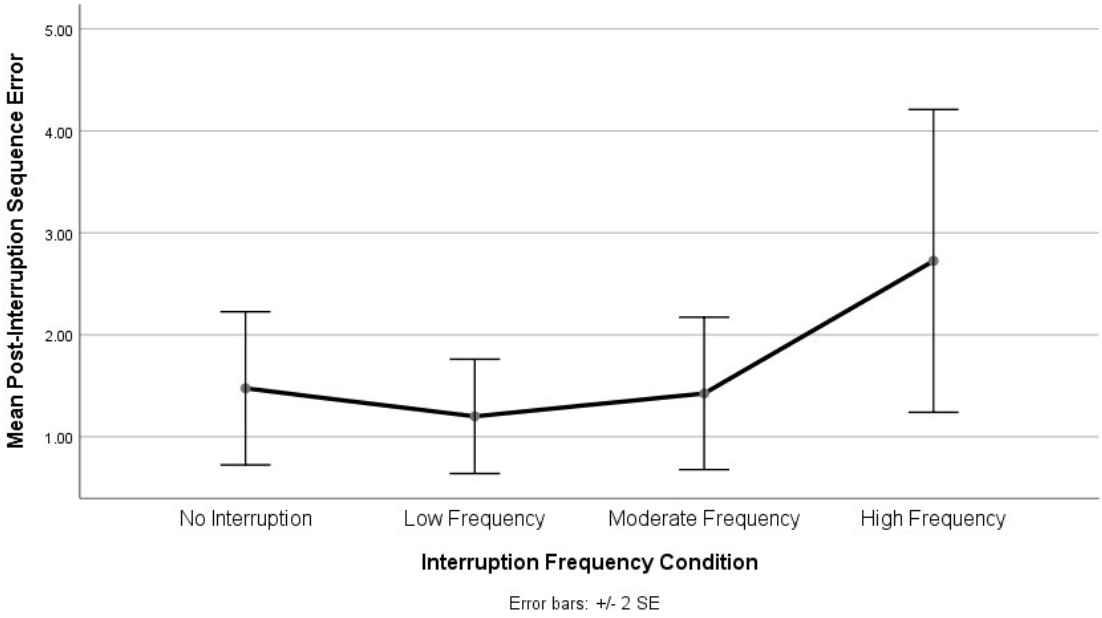


Figure 14 Mean post interruption sequence error across interruption frequency.

Frequency Analysis 3 - General effect of interruption frequency, CAMROSE task step, and the interaction of both on sequence errors.

A 4 (Interruption Frequency: No Interruption, Low Frequency, Moderate Frequency, High Frequency) x 7 (CAMROSE Task Step: Step 1 (C), Step 2 (A), Step 3 (M), Step 4 (R), Step 5 (O), Step 6 (S), Step 7 (E)) repeated measures ANOVA was used to explore the main effect of interruption complexity and CAMROSE task step as well as the interacting effect on sequence errors (Figure 20). Results indicates a significant main effect of interruption frequency on the number of sequence errors made on a CAMROSE task step $F(1.85, 72.25) = 4.61$, MSE = 1.39, $p = .015$, $\eta^2_p = .106$. Despite this significant finding, and a linear trend in that as frequency increases so do the number of sequence errors, pairwise comparisons using Bonferroni post-hoc analysis revealed no significant difference between frequency conditions on the number of sequence errors being made on a CAMROSE task step. There was no significant main effect of CAMROSE task step on the number of sequence errors being made, $F(1.72, 67.35) = 2.60$, MSE = 5.68, $p > .05$, $\eta^2_p = .063$. There was also no significant interaction between interruption complexity and CAMROSE task step on the number of sequence errors being made, $F(4.01, 156.66) = .960$, MSE = 1.94, $p < .05$, $\eta^2_p = .024$.

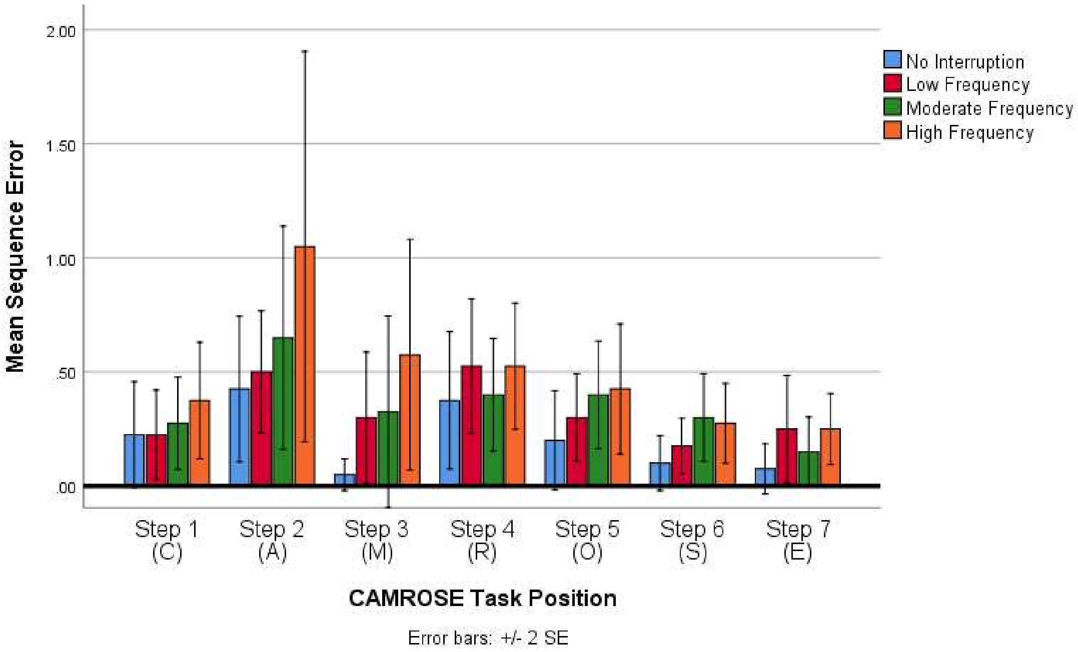


Figure 15 Sequence errors across each CAMROSE task step for each interruption frequency condition.

Frequency Analysis 4 - Comparison of post-interruption sequence errors (errors occurring directly after the interruption upon resumption of primary task) compared to no interruption (control) sequence errors through comparison of interruption frequency, CAMROSE task step, and the interaction of both.

A 4 (Interruption Frequency: No Interruption, Low Frequency, Moderate Frequency, High Frequency) x 7 (CAMROSE Task Step: Step 1 (C), Step 2 (A), Step 3 (M), Step 4 (R), Step 5 (O), Step 6 (S), Step 7 (E)) repeated measures ANOVA was used to explore the main effect of interruption frequency and CAMROSE task step as well as the interacting effect on post-interruption sequence errors (Figure 16). A significant main effect was found on interruption frequency on the number of post-interruption sequence errors made on a CAMROSE task step $F(1.71, 66.68) = 4.73$, MSE = 1.01, $p = .016$, $\eta^2_p = .108$. Bonferroni pairwise comparisons indicate significantly more post-interruption sequence errors were being made in the High-Frequency condition ($M = .204$, $SD = .670$) compared to the Low ($M = .171$, $SD = .171$) and Moderate ($M = .204$, $SD = .203$) Frequency conditions with p*'s* <.05. There was no other significant difference in the between frequency manipulations with p*'s* >.05. There was no significant main effect of CAMROSE step on the number of post-interruption sequence errors being made, $F(3.08, 120.20) = 1.60$, MSE = .459, $p > .05$, $\eta^2_p = .039$.

There was no significant interaction between interruption frequency and CAMROSE task position on the number of post-interruption sequence errors being made $F(5.85, 228.31) = 1.74$, MSE = .612, $p > .05$, $\eta^2_p = .043$.

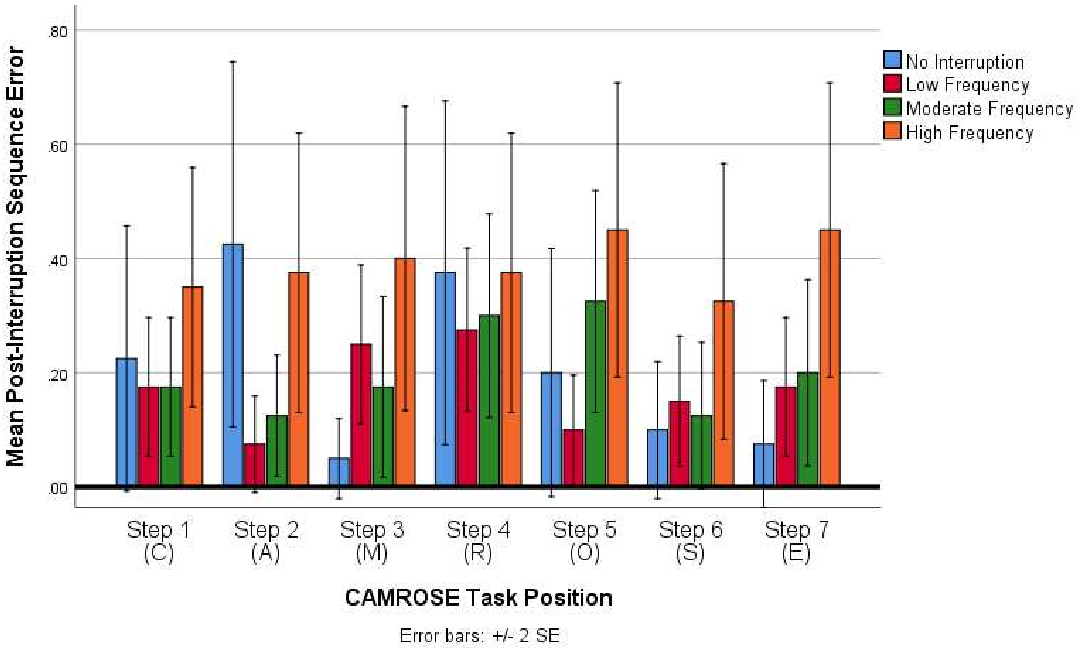


Figure 16 Post interruption sequence errors across each CAMROSE task step for each interruption frequency condition.

Frequency Analysis 5 - General effects of interruption frequency on non-sequence errors during CAMROSE Medication Pre-Administration Task

A repeated measure analysis of variance (ANOVA) was used to test the effects of interruption frequency (No Interruption, Low Frequency, Moderate Frequency, High Frequency) on the number of non-sequence errors made. Results indicated there was no significant effect of interruption frequency on the number of non-sequence errors being made, $F(3, 117) = 1.95$, MSE = .446, $p > .05$, $\eta^2_p = .048$. Despite such finding there did appear to be some unusual trends in the data (Figure 17), with the most non-sequence errors occurring in the No Interruption condition (M = .625, SD = 1.27) compared to the Low (M = .375, SD = .806), Moderate (M = .275, SD = .554), and High Frequency (M = .450, SD = 1.10) conditions.

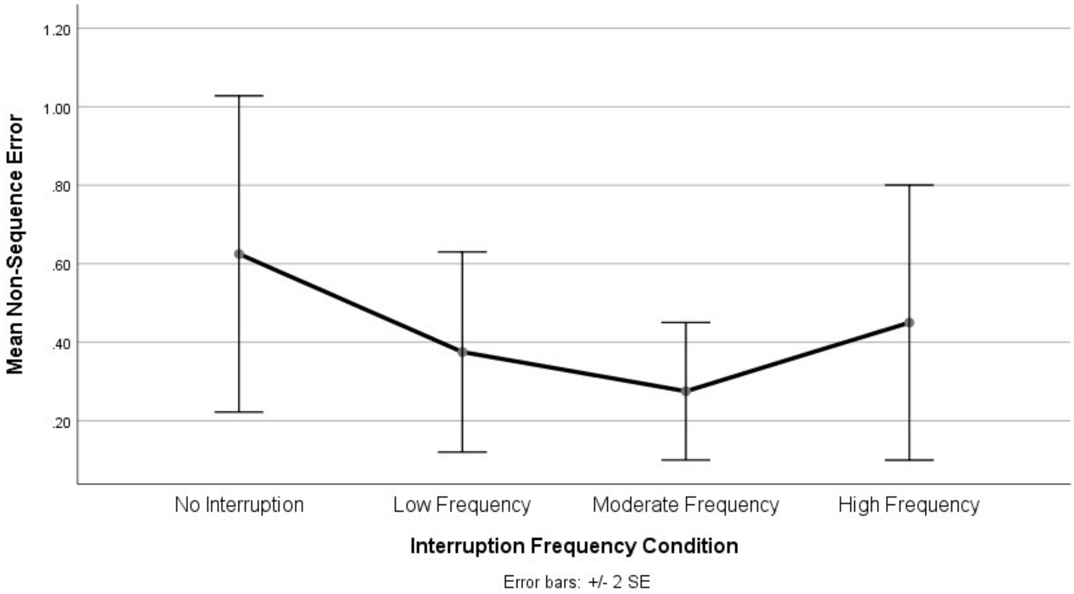


Figure 17 Mean non-sequence errors across interruption frequency conditions.

Frequency Analysis 6 - Comparison of post-interruption sequence errors (errors occurring directly after the interruption upon resumption of primary task) compared to no interruption (control) non-sequence errors across interruption frequency manipulations.

A repeated measure ANOVA was used to explore whether the number of non-sequence errors significantly increased/decreased directly after resuming a primary task (post-interruption errors) across each frequency manipulation compared to the non-sequence errors observed in the control condition. There was significant effect of interruption frequency on the number of non-sequence errors being made, *F*(1.31, 51,07) = 8.35, MSE = .822, *p* <.01, η^2_p = .176. Bonferroni pairwise comparisons reveal that significantly less non-sequence post interruption errors were made in the Low Frequency (*M* = .025, *SD* = .158), Moderate Frequency (*M* = .075, *SD* .266), and High Frequency (*M* = .175, *SD* = .594) conditions compared to non-sequence errors being made in the No Interruption condition (*M* = .625, *SD* = 1.27) with all *p's* >.05.

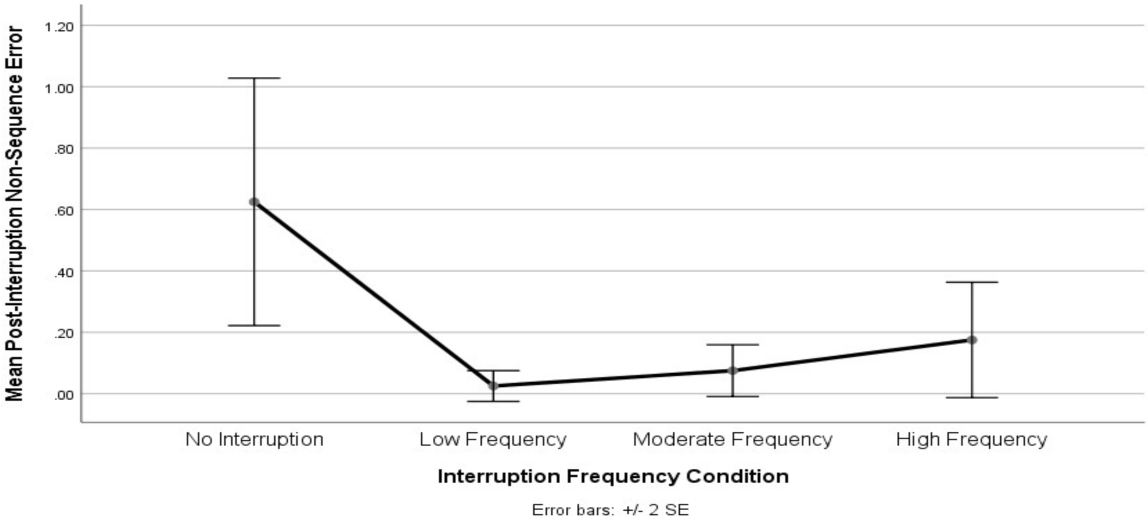


Figure 18 Mean post-interruption non-sequence errors across interruption frequency conditions.

Frequency Analysis 7 - General effect of interruption frequency, CAMROSE task step, and the interaction of both on non-sequence errors.

A 4 (Interruption Frequency: No Interruption, Low Frequency, Moderate Frequency, High Frequency) x 7 (CAMROSE Task Step: Step 1 (C), Step 2 (A), Step 3 (M), Step 4 (R), Step 5 (O), Step 6 (S), Step 7 (E)) repeated measures ANOVA was used to explore the main effect of interruption frequency and CAMROSE task step as well as the interacting effect on non-sequence errors (Figure 23). There was no significant main effect of interruption frequency on the number of non-sequence errors being made on each task step, *F*(3, 117) = 2.01, MSE = .065, $p > .05$, $\eta^2_p = .049$. There was a significant main effect of CAMROSE task step on the number of non-sequence errors being made, F(1.14, 44.79) = 4.81, MSE = 1.60, $p = .029$, $\eta^2_p = .110$. Bonferroni pairwise comparisons revealed that whilst more non-sequence errors were made on CAMROSE task step 1 (*M* = .275, *SD* = 1.21) compared to all other CAMROSE task steps, none of these were significant with all p's >.05. There was no significant interaction between interruption frequency and CAMROSE task step on the number of non-sequence errors being made, *F*(4.63, 180.74) = 1.94, MSE = .264, $p > .05$, $\eta^2_p = .047$.

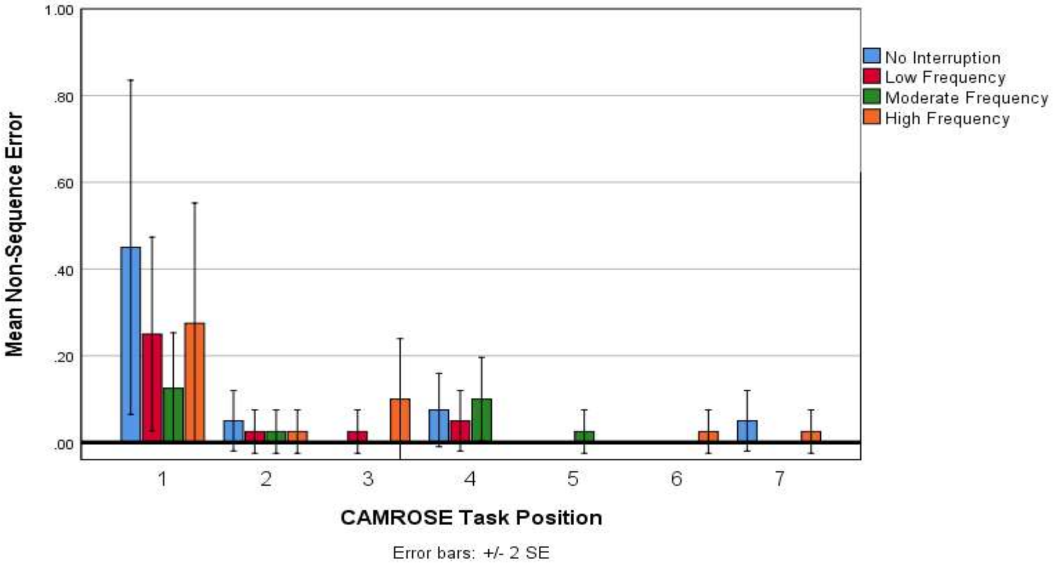


Figure 19 Non-sequence errors across each CAMROSE task step for each interruption frequency condition.

Frequency Analysis 8 - Comparison of post-interruption non-sequence errors (errors occurring directly after the interruption upon resumption of primary task) compared to no interruption (control) sequence errors through comparison of interruption frequency, CAMROSE task step, and the interaction of both.

A 4 (Interruption Frequency: No Interruption, Low Frequency, Moderate Frequency, High Frequency) x 7 (CAMROSE Task Step: Step 1 (C), Step 2 (A), Step 3 (M), Step 4 (R), Step 5 (O), Step 6 (S), Step 7 (E)) repeated measures ANOVA was used to explore the main effect of interruption frequency and CAMROSE task step as well as the interacting effect on post-interruption non-sequence errors (Figure 24). A significant main effect was revealed on interruption frequency on the number of post-interruption non-sequence errors made on a CAMROSE task step $F(1.31, 51.07) = 8.35$, MSE = .117, $p < .01$, $\eta^2_p = .176$. Bonferroni pairwise comparisons indicate that more non-sequence errors were being made in the No Interruption condition ($M = .089$, $SD = .182$) compared to post-interruption non-sequence errors in the Low Frequency ($M = .004$, $SD = .026$), Moderate Frequency ($M = .011$, $SD = .044$), and High Frequency conditions ($M = .025$, $SD = .096$) with all *p's* <.05. There was no other significant difference with all p's >.05. There was no significant main effect of CAMROSE task step on the number of post-interruption non-sequence errors being made, $F(1.44, 56.16) = 3.83$, MSE = .305, $p > .05$, $\eta^2_p = .089$. There was also no significant interaction between interruption frequency and CAMROSE task step on the number on post-interruption non-sequence errors being made $F(3.12, 59.66) = 3.84$, MSE = .812, $p > .05$, $\eta^2_p = .090$.

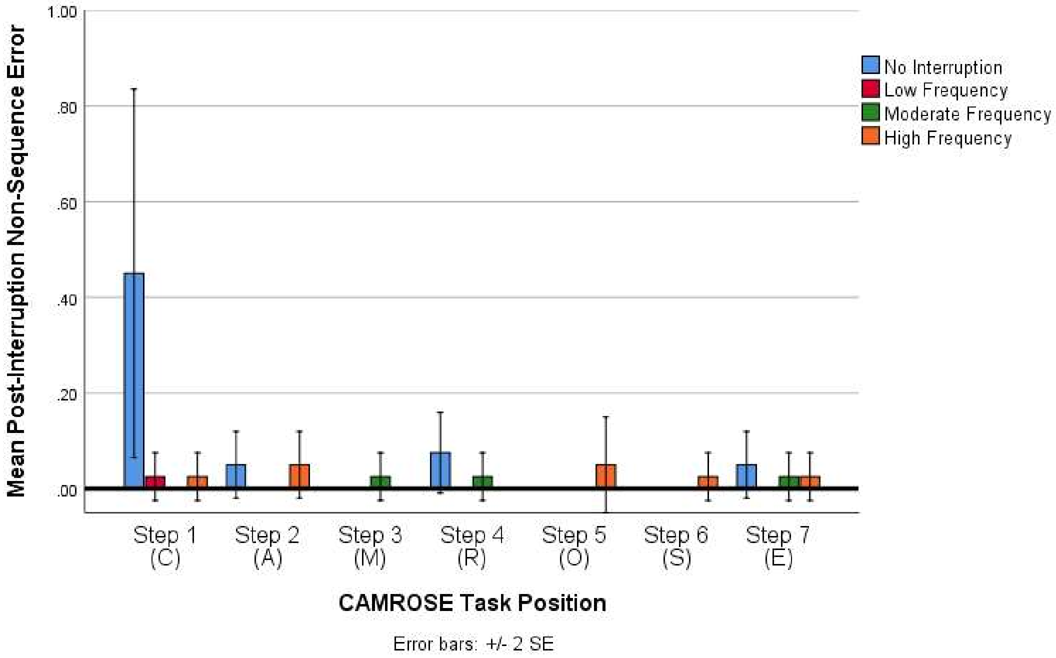


Figure 20 Post interruption non-sequence errors across each CAMROSE task step for each interruption frequency condition.

Frequency Analysis 9 - General comparison of inter-action interval (time between to respond to each CAMROSE task step) across each interruption frequency condition.

A repeated measure analysis of variance (ANOVA) was used to test the effects of interruption frequency (No Interruption, Low Frequency, Moderate Frequency, High Frequency) on the average time (seconds) to make a response on a task step (inter-action interval). There was a significant effect of interruption frequency on the inter-action interval, *F*(2.46, 95.95) = 12.54, MSE = .590, $p < .001$, $\eta^2_p = .243$. Bonferroni pairwise comparisons revealed that participants were taking significantly longer to make a response in the Moderate Frequency (*M* = 2.94, *SD* =) and High Frequency (*M* = 3.26, *SD* =) conditions compared to the No Interruption condition (*M* = 2.37, *SD* =) with *p's* <.001. Furthermore, responses were significantly longer in the High Frequency condition compared to the Low Frequency condition (*M* = 2.61, *SD* =) *p* = <.01 (Figure 21).

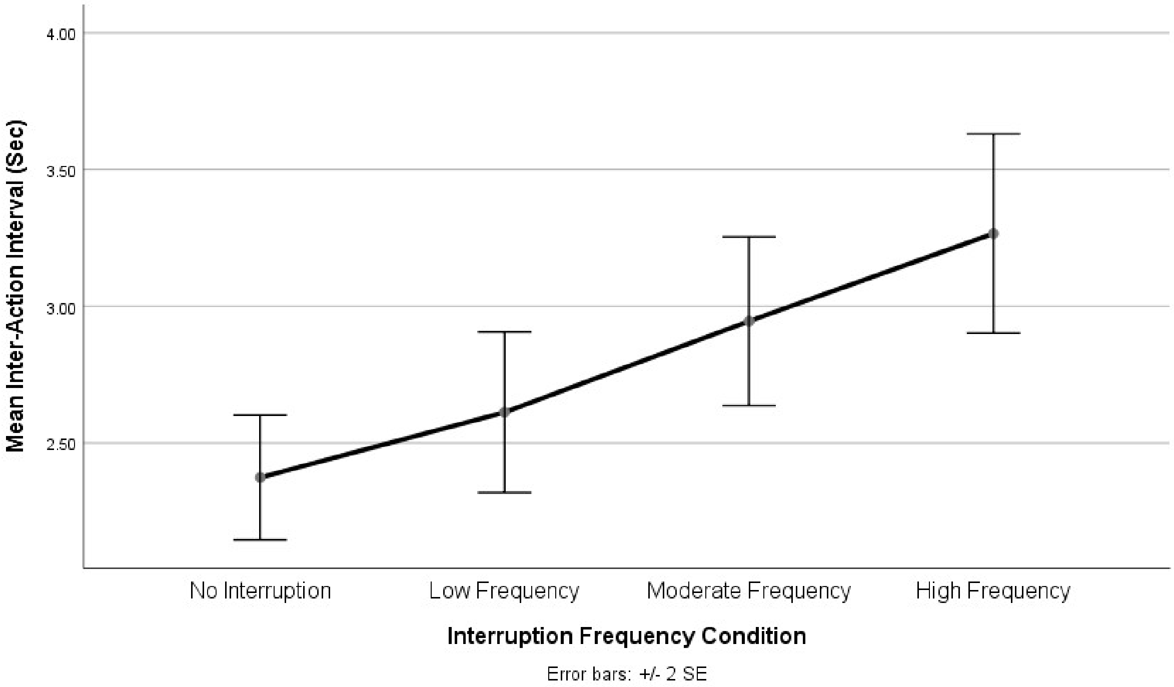


Figure 21 Comparison of inter-action interval across interruption frequency

Frequency Analysis 10 - Comparison of post-interruption resumption lag (time between end of interruption and first response back onto primary task) compared to inter-action interval.

Paired samples t-tests were used to test for differences between resumption lag and inter-action interval on each frequency manipulation. Results indicated that resumption lag was significantly higher (*M* = 4.20, *SD* = 1.96) than inter-action interval (*M* = 2.61, *SD* = .927) in the Low Frequency condition *t*(39) = 6.99, *p* <.001, significantly higher (*M* = 3.47, *SD* = 1.19) than inter-action interval (*M* = 2.94, *SD* = .975) in the Moderate Frequency condition *t*(39) = 7.37, *p* <.001, and significantly higher (*M* = 3.78, *SD* = 1.56) than inter-action interval (*M* = 3.26, *SD* = 1.15) in the High Frequency condition *t*(39) = 6.39, *p* <.001 (Figure 22).

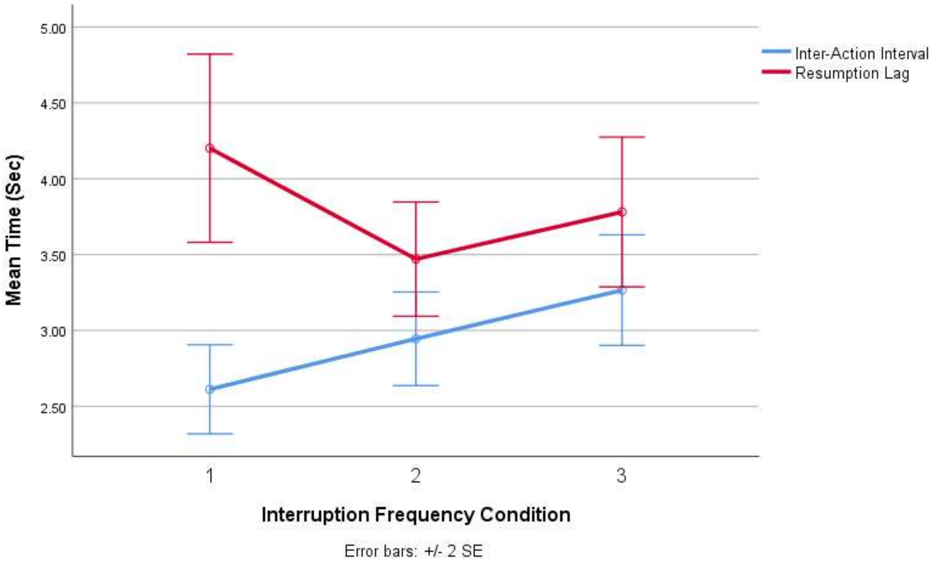


Figure 22 Comparison of inter-action interval and resumption lag across interruption frequency.

Frequency Analysis 11 - Comparison of resumption lag compared to no interruption (control) inter-action interval across interruption frequency, CAMROSE task step, and the interaction of both.

A 4 (Interruption Frequency: No Interruption, Low Frequency, Moderate Frequency, High Frequency) x 7 (CAMROSE Task Step: Step 1 (C), Step 2 (A), Step 3 (M), Step 4 (R), Step 5 (O), Step 6 (S), Step 7 (E)) repeated measures ANOVA was used to explore the main effect of interruption frequency and CAMROSE task step as well as the interacting effect on resumption lag (Figure 23). A significant main effect was found of interruption frequency on the resumption to primary task on a CAMROSE task step $F(1.38, 54.01) = 165.28$, MSE = 82.10, $p < .001$, $\eta^2_p = .809$. Bonferroni pairwise comparisons indicated that it took longer to resume a task step after an interruption in the Low Frequency (*M* = 4.20, *SD* = 1.96), Moderate Frequency (*M* = 3.47, *SD* = 1.19) and High Frequency (*M* = 11.34, *SD* = 4.68) conditions compared to the average time to complete the same task step in the No Interruption condition (*M* = .089, *SD* = .721) with all *p's* <.001. Furthermore, the average time to resume the primary task was significantly higher in the High Frequency condition compared to the Low and Moderate Frequency conditions with *p's* <.001.

There was a significant main effect of the CAMROSE task step on the average time to either make a response (No Interruption condition) or resume back to the primary task, $F(6, 234) = 8.32$, MSE = 9.74, $p < .001$, $\eta^2_p = .176$. It was revealed in the Bonferroni pairwise comparisons that the average response time and/or resumption was significantly more on CAMROSE task step 3 (M) (*M* = 5.87, *SD* = 2.29) compared to CAMROSE task step 1 (C) (*M* = 4.71, *SD* = 2.36), step 2 (A) (*M* = 4.04, *SD* = 1.77), step 5 (O) (M = 4.44, *SD* = 1.93) and step 6 (S) (*M* = 3.95, *SD* = 2.09) with all *p's* <.05. Furthermore, CAMROSE task step 6 (S) was significantly lower than step 4 (R) (*M* = 5.46, *SD* = 2.99) and step 7 (E) (*M* = 4.92, *SD* = 2.15) with *p's* <.05.

There was a significant interaction between interruption frequency and CAMROSE task step on the average time to resume the primary task $F(6.95, 271.38) = 2.42$, MSE = 24.43, $p < .05$, $\eta^2_p = .059$. Bonferroni post-hoc analysis revealed a trend in that resumption time was higher on every CAMROSE task step when they occurred in a Low, Moderate or High Frequency condition compared to the same task step in the No Interruption condition with all p's <.001.

The average time to make a response on a task step was significantly shorter on CAMROSE task step 1 (C) when in the No Interruption condition compared to resumption on the same task step when occurring in all other Frequency conditions with *p's* <.001. The time to resume the same task step was significantly higher when resuming in the High Frequency condition compared to the Low and Moderate Frequency conditions. A similar pattern was evident in that across all CAMROSE task steps, when occurring in the High Frequency condition the resumption significantly higher than the same task step occurring in either the Low or Moderate Frequency condition with all *p's* <.001.

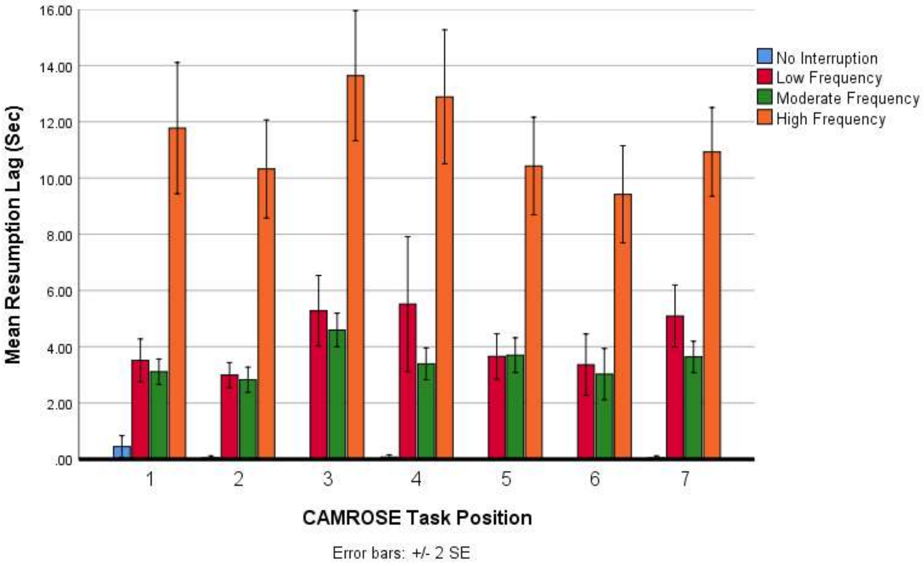


Figure 23 Resumption lag across each CAMROSE task step for each interruption frequency condition.

Summary

When compared to no interruptions, task interruptions significantly increase the number of sequence errors made. While there was a trend that as interruption frequency increased, so did the number of sequence errors, only high-frequency interruptions significantly increased the number of sequence errors when compared to the no interruption condition. This only partially supported the sequence error predictions.

There was an unusual trend for non-sequence errors in that task interruptions reduced such errors when compared to the no-interruption condition. This does, however, support hypothesis two in that task interruptions had no significant impact on non-sequence errors.

There were significant differences found in the inter-action intervals between interruption frequency and no interruption conditions. Participants were taking significantly longer to make a response in the moderate frequency and high frequency conditions compared to the no Interruption condition. Furthermore, responses were significantly longer in the high frequency condition compared to the low frequency condition. When comparing inter-action intervals directly with resumption time, resumption lag was significantly higher than the inter-action interval across all frequency conditions supporting the predictions made on resumption time.

Sequence errors that occurred upon resumption of the primary task were significantly more in the interruption frequency conditions. Interestingly, whilst not significant, fewer post-interruption sequence errors were made in the low and moderate frequency conditions compared to the no interruption condition. There were significantly more post-interruption sequence errors being made when interruptions were high in frequency compared to no interruptions, low and moderate frequency interruptions. This to some extent provides support for predictions made on post-interruption errors in that more frequent interruptions impacted performance.

When combined with experiment 1, it appears that when participants complete the CAMROSE task, task interruptions have a significant effect on performance if they are simple or occur frequently. The frequency of task interruptions in experiment 1 was set to match the moderate frequency in experiment 2. Given that significant effects were only identified at a high frequency (for low complex interruptions), it is possible that frequency and complexity have different effects on performance. While this provides additional insights into the nature of clinical task interruptions, exploring other characteristics would allow for explanation extensions. This is especially important to consider in a healthcare setting, where healthcare professionals face task interruptions from a variety of sources. So far, the results suggest that limiting task interruptions and taking into account the complexity of interruptions may reduce negative effects. However, in both experiments 1 and 2, interruptions were initiated by a photo of a nurse and synchronised audio (to mimic face-to-face interruptions). It would be beneficial to further investigate the role of source in the initiation of task interruptions, which would allow for a better understanding of the role such characteristics play in clinical task performance.

Experiment 3: Interruption Source

Experimental Hypotheses

Task interruptions start from a source. Thus, interruptions can be made face-to-face, auditorily (e.g., telephone), or electronically (e.g., email). Interruptions are common in healthcare professionals' complex socio-technical environment. Few studies have examined how interruption modalities affect performance. Understanding such effects may help target interventions that best fit healthcare norms for source prioritisation (e.g., prioritising a beeper over a telephone as the beeper is to be used only in emergencies; Wajcman & Rose, 2011). While clinical task interruptions can come from many sources, a better understanding of their direct effects is needed. When administering medication, this may be especially important. This may help guide proposed interventions in specific clinical tasks (e.g., if emails are more problematic during medication, could user design principles help minimise emails at these critical times?). The following hypotheses are based on the literature reviewed in relation to the effects of interruption sources on performance. It is predicted that there will be more sequence errors in interruption source conditions than in no interruption conditions, with email interruptions causing the most errors (H1). There will be no difference in non-sequence errors between interruption sources and no interruptions, due to interruptions interfering with the ability to control a sequence rather than individual step performance (H2). The time to resume the primary task after an interruption will be longer than the average time to respond, with email interruptions resulting in a decrease in resumption time (H3). Email interruptions will have higher post-interruption errors than face-to-face and audio interruptions (H4).

Method

Participants

An opportunity sampling method was used to recruit 33 psychology students aged 18–21 years of age (M = 19.12; SD = .78). All 33 participants were female and were given course credits for their participation linked to their UG BSc Psychology degree research methods training. All participants had normal-corrected vision and hearing and were English first language or highly proficient in English as a second language.

Design

A repeated measures design was utilized with one main independent variable: the communication method in which the interruption was initiated, defined as the source of clinical task interruptions. Source was determined by the communication of interruptions that occur within an experimental block and had four levels: No Interruptions (Control), Face to Face Interruptions, Phone/Audio Interruptions, Email Interruptions. Face to face interruptions would be in the same format previous experiments, whereas phone/audio interruptions would entail an audio description without the presence of the nurse image, whilst email interruptions would entail a mock email presenting interruption scenario (Figure 24). All interruptions were low in complexity as defined in experiment 1.

If a patient has a temperature of 39.2, what is the first stage required?

Face-to-Face Interruption

Phone/Audio Interruption

Email Interruption

Figure 24 Example of participant interface experience for each interruption source

Furthermore, interruptions that occur within points of the experimental task where cognitive load is likely to be higher (mid-way through the sequence) may have more of a profound effect on performance than interruptions occurring at points where cognitive load is likely to be lower (at the beginning of the task; Altmann & Trafton, 2015). Given this, interruption position was a variable controlled for whereby interruptions were designed to occur at least twice on each sequential step of the primary task (CAMROSE) throughout the experiment.

The same dependent variables (DV) will be focused on here as they were in from the proceeding experiment. Therefore DV-1 was sequence errors which was determined by the incorrect step performed (e.g., a step that does not logically follow on from the previous step). DV-2 was non-sequence errors when the correct step is performed but with the wrong response (each step has two possible responses). Both DV's will provide insights into task accuracy both overall and post-interruption (e.g., errors that occur directly after an interruption upon resumption of the primary task). Timing measures (such as time to resume to primary task – resumption lag) were also recorded to measure task and resumption efficiency. DV-3 was a measure of inter-action interval (resumption lag) by recording the time taken from the end of the interruption until the first keyboard response back on the primary task (Cades et al, 2008). This will allow for the assessment in differences in disruptiveness between interruption task complexity. DV-4 was the reaction time on each step of the primary and interruption task. In order to assess to perceived cognitive workload of participants on each experimental condition, and help validate that each variance in each condition, cognitive workload was assessed.

Each step of the experimental task was considered as a trial (7 trials = 1 full sequence), and an experimental block contained 5 sequences (1 block = 5 sequences = 35 trials). Each block represented a within-participant frequency level, so a total of 4 blocks (Total = 140 trials). During each experimental block, each sequence was continuous until all trials were completed (e.g., E was followed by C). At the end of each experimental block, participants were given the opportunity to take a break before beginning the next block. Interruption source was therefore counterbalanced using the same Latin Square as in previous experiments, creating 4 versions of the experiment. The same images of the routinely scheduled medicines chart occur within each experimental block, but the order of the images was randomly pre-selected using an online random sequence generator (Random.org; https://www.random.org/sequences/). Where the interruptions occurred varied depending on the source condition but were controlled to occur at least twice on each task position.

Materials

The primary and interruption task used in this experiment is the CAMROSE Medication Pre-Administration Task and Clinical Decision-Making Task explained in Section 4.2.1/4.2.2. Experiments were running within psychology laps on induvial workstations (each separated by a partition) that held between 4-16 participants. Each workstation had a desktop PC, computer mouse and keyboard, and over-ear headphones. To respond accordingly to the interruptions, participants had a paper reference version of the clinical score chart and actions required present at their workstation. Interruptions were initiated by an image of a nurse and audio recording of a clinical If-Then scenario. Reponses were made on the computer after the interruption and participants would press the ‘enter’ key on the keyboard once they were finished and returned to the primary task where they left off. Cognitive load was measured at the end of each experimental block using an electronic variation of the NASA Task Load Index (NASA-TLX; Hart & Staveland, 1988). This was assessed on a Likert type scale (e.g., ‘How mentally demanding was the task?’, ‘How hurried or rushed was the pace of the task?’). Increments of high, medium, and low estimates for each point result in 21 gradations on the scales. The scale was programmed into the experiment so that participants could complete the scale at the end of each experimental block and would allow for the assessment of individual workload on each experimental condition.

Procedure

Upon entering the experimental room, participants were asked to read the participant information and experimental instructions before providing informed consent to participate. The experimental instructions were also explained in detail by the researcher, expressing the importance of remembering the acronym CAMROSE and its associated responses. Participants were encouraged to ask questions regarding any elements of the primary task to ensure they fully understood what was expected. After explanation of how to perform the primary task, participants completed a short practice stage without any interruptions which consisted of 14 trials. During all the practice trials, the CAMROSE acronym and its associated responses were present to help participants learn the procedure. Again, participants were encouraged to use this as much as needed throughout the practice trials.

Upon completion of the practice trials for the primary task, the researcher explained the interruption task, and participants were instructed to complete the interruption task by providing a clinical score and required response based upon the if-then scenario presented, and then to return to the primary task where they had left off. Participants were not instructed directly during the briefing that this was an interruption task but rather a secondary task in which performance on both tasks were equally important for the experiment. Participants completed another round of 14 practice trials, this time including a sample of interruptions they were expected to experience throughout the experiment phase. During this phase, participants were requested to wear the over-ear headphones provided until they had finished. The acronym and possible responses continued to be present for these practice trials as well. After the practice trials participants were once again encouraged to ask questions if they were unsure and/or complete another practice run if they wished to do so. If participants were happy to continue, before beginning, all paperwork not related to the experiment including the acronym was collected, and pens and phones were asked to be put away. Participants wore the headphones throughout the whole experiment. At the end of the main experimental phase, participants were fully debriefed. Total experimental time was approx. 60 minutes.

Results

Interruption Source Analysis 1 - General effects of interruption source on sequence errors during CAMROSE Medication Pre-Administration Task.

A repeated measure analysis of variance (ANOVA) was used to test the effects of interruption source (No Interruption, Email Interruptions, Face to Face Interruptions, Phone Interruptions) on the number of sequence errors made. Results indicated a significant effect of interruptions on the number of sequence errors being made, $F(3, 96) = 11.86$, MSE = 7.01, $p < .001$, $\eta^2_p = .271$, with participants making significantly less sequence errors in the no interruption condition (*M* = .879, *SD* = 1.84) compared to the Email (*M* = 4.27, *SD* = 4.17), Face to Face (*M* = 4.03, *SD* = 3.95), and Phone (*M* = 3.78, *SD* = 3.73) source conditions with all *p's* < .001. There was no significant difference in the number of sequence errors being made between the Email, Face to Face and Phone conditions with all *p's* > .05, despite there being a visible trend in that most sequence errors were made in the Email condition (Figure 25).

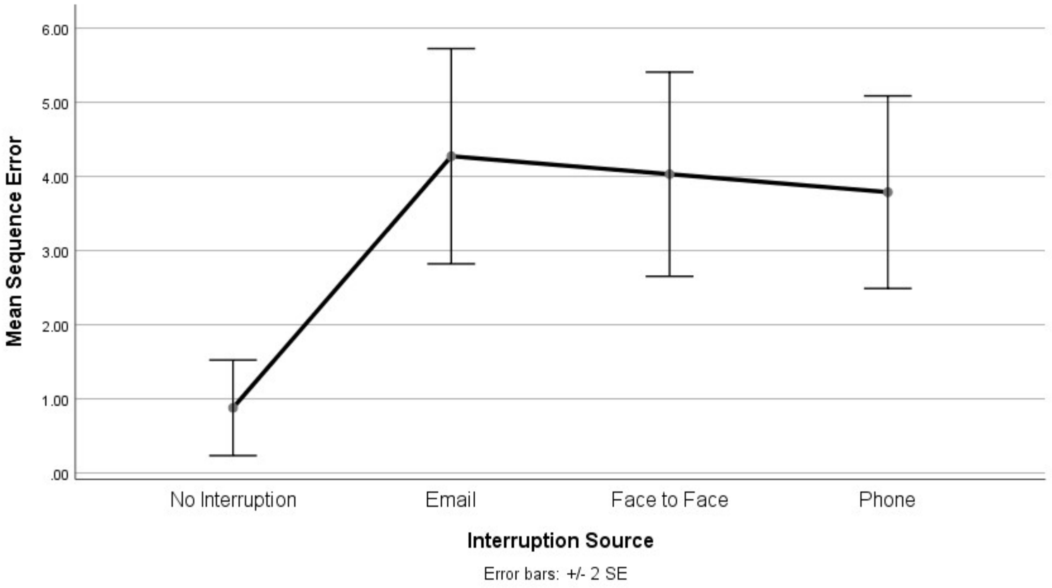


Figure 25 Mean sequence error across interruption source conditions.

Interruption Source Analysis 2 - Comparison of post-interruption sequence errors (errors occurring directly after the interruption upon resumption of primary task) compared to no interruption (control) sequence errors.

The same repeated measure ANOVA was used to explore whether the number of sequence errors significantly increased/decreased directly after resuming a primary task (post-interruption errors) across each interruption source manipulation compared to the errors observed in the control condition. Results indicated a significant effect of interruption source on the number of post-interruption sequence errors being made, $F(2.03, 64.98) = 11.68$, MSE = 5.17, $p < .001$, $\eta^2_p = .267$. A similar trend was apparent as that in interruption source analysis 1 (Figure 26) with Bonferroni comparisons revealing significantly more post-interruption sequence errors were being made in the Email condition ($M = 3.48$, $SD = 3.22$) compared to sequence errors being made in the No Interruption condition ($M = .878$, $SD = 1.84$, $p <.01$), and post-interruption sequence errors in the Face to Face ($M = 2.03$, $SD = 2.31$, $p <.01$) and Phone conditions ($M = 1.48$, $SD = 1.73$, $p <.001$). There were no other significant differences in post-interruption sequence errors.

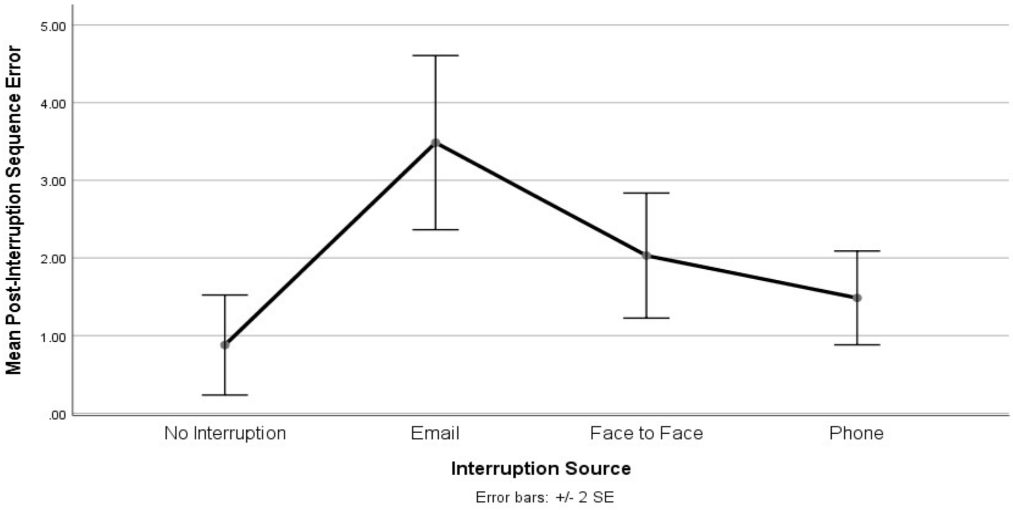


Figure 26 Mean post interruption sequence error across interruption source conditions.

Interruption Source Analysis 3 - General effect of interruption source, CAMROSE task step, and the interaction of both on sequence errors.

A 4 (Interruption Source: No Interruption, Email Interruption, Face to Face Interruption, Phone Interruption) x 7 (CAMROSE Task Step: Step 1 (C), Step 2 (A), Step 3 (M), Step 4 (R), Step 5 (O), Step 6 (S), Step 7 (E)) repeated measures ANOVA was used to explore the main effect of interruption source and CAMROSE task step as well as the interacting effect on sequence errors (Figure 27). Results indicate a significant main effect of interruption source on the number of sequence errors made on a CAMROSE task step *F*(3, 96) = 12.37, MSE = 1.06, *p* < .001, η^2_p = .279. Pairwise comparisons using Bonferroni post-hoc analysis revealed a similar trend in comparative analyses in that significantly less sequence errors were made on a task step in the No Interruption condition (*M* = .134, *SD* = .276) compared to the Email (*M* = .662, *SD* = .639, *p* <.001), Face to Face (*M* = .597, *SD* = .578, *p* <.01), and Phone conditions (*M* = .550, *SD* = .539, *p* <.01), but there was no significant difference between any of the other conditions on the number of sequence errors made on task steps (*p's* >.05). There was no significant main effect of CAMROSE task step on the number of sequence errors, *F*(3.40, 109.08) = 1.46, MSE = 2.39, *p* > .05, η^2_p = .044. There was no significant difference between any of the other CAMROSE task steps on the number of sequence errors being made with all *p's* >.05. There was no significant interaction between interruption source and CAMROSE task step on the number of sequence errors being made, *F*(8.01, 256.37) = 1.31, MSE = 1.37, *p* >.05, η^2_p = .040.

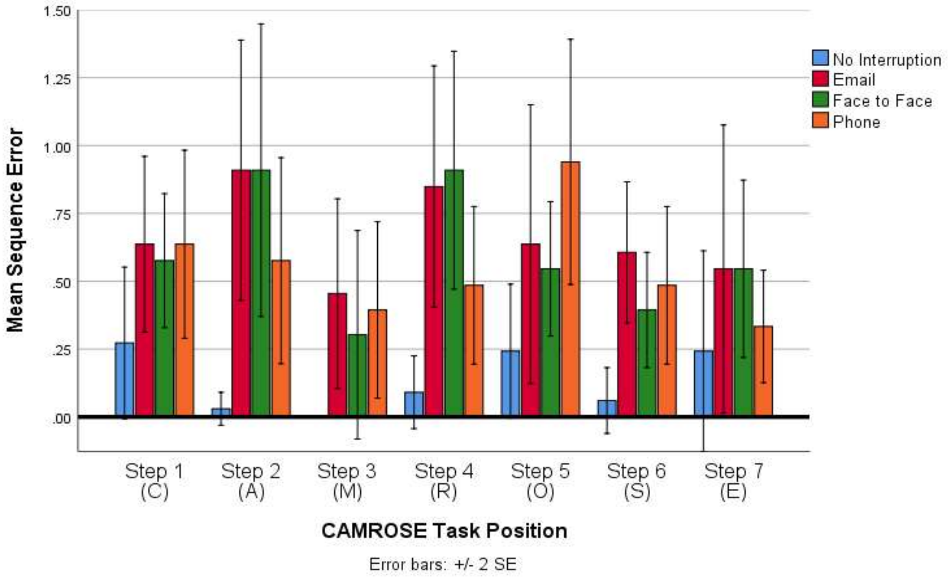


Figure 27 Sequence errors across each CAMROSE task step for each interruption source condition.

Interruption Source Analysis 4 - Comparison of post-interruption sequence errors (errors occurring directly after the interruption upon resumption of primary task) compared to no interruption (control) sequence errors through comparison of interruption source, CAMROSE task step, and the interaction of both.

A 4 (Interruption Source: No Interruption, Email Interruption, Face to Face Interruption, Phone Interruption) x 7 (CAMROSE Task Step: Step 1 (C), Step 2 (A), Step 3 (M), Step 4 (R), Step 5 (O), Step 6 (S), Step 7 (E)) repeated measures ANOVA was used to explore the main effect of interruption source and CAMROSE task step as well as the interacting effect on post-interruption sequence errors (Figure 28).

A significant main effect was found for interruption source on the number of post-interruption sequence errors made on a CAMROSE task step *F*(2.06, 65.99) = 11.12, MSE = .739, $p < .001$, $\eta^2_p = .258$. Bonferroni pairwise comparison revealed significantly more post-interruption sequence errors were made on a CAMROSE task step in the Email condition (*M* = .498, *SD* = .460) compared to sequence errors made in the No Interruption condition (*M* = .134, *SD* = .276, $p <.01$) and post-interruption sequence errors in the Face to Face (*M* = .290, *SD* = .330, $p <.01$) and Phone conditions (*M* = .212, *SD* = .247, $p <.001$). There was a non-significant effect of CAMROSE step on the number of post-interruption sequence errors, *F*(4.35, 139.20) = 2.49, MSE = .341, $p > .05$, $\eta^2_p = .072$. There was no significant interaction between interruption source and CAMROSE task position on the number of post-interruption sequence errors being made *F*(7.30, 233.58) = 1.87, MSE = .585, $p > .05$, $\eta^2_p = .055$.

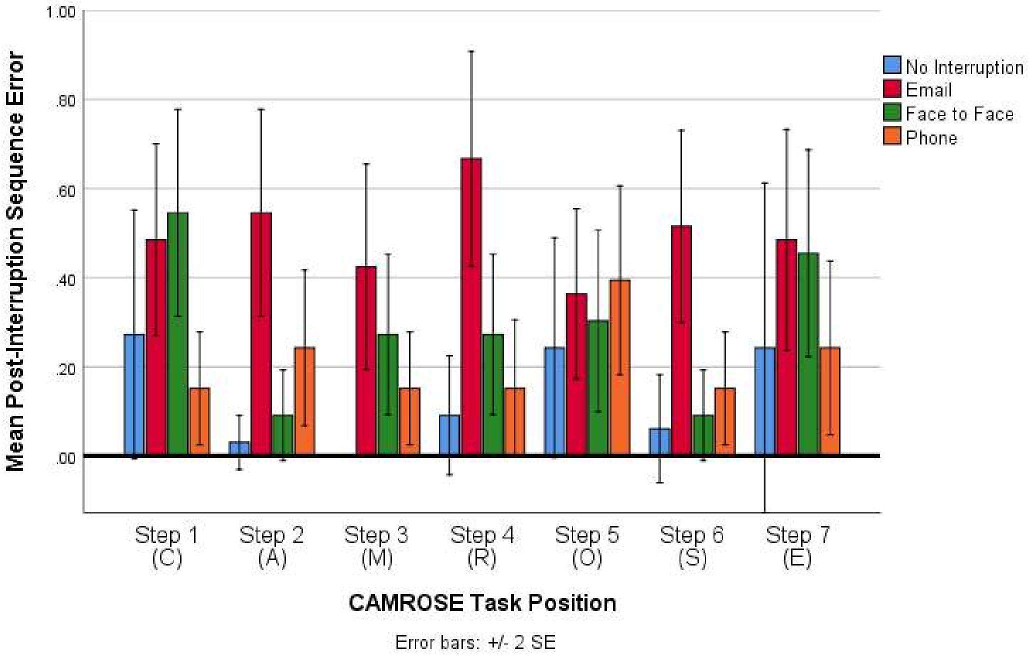


Figure 28 Post interruption sequence errors across each CAMROSE task step for each interruption source condition.

Interruption Source Analysis 5 - General effects of interruption source on non-sequence errors during CAMROSE Medication Pre-Administration Task

A repeated measure analysis of variance (ANOVA) was used to test the effects of interruption source (No Interruption, Email Interruption, Face to Face Interruption, Phone Interruption) on the number of non-sequence errors made. Results indicated there was no significant effect of interruptions source on the number of non-sequence errors being made across interruption manipulations, *F*(2.17, 69.53) = .479, MSE = .662, $p > .05$, $\eta^2_p = .015$. Whilst not significant, the Face-to-Face condition (M = .575, SE = .867) yielded the most non-sequence errors whilst the Phone condition had the least (M = .393, SE = .899) (Figure 29)

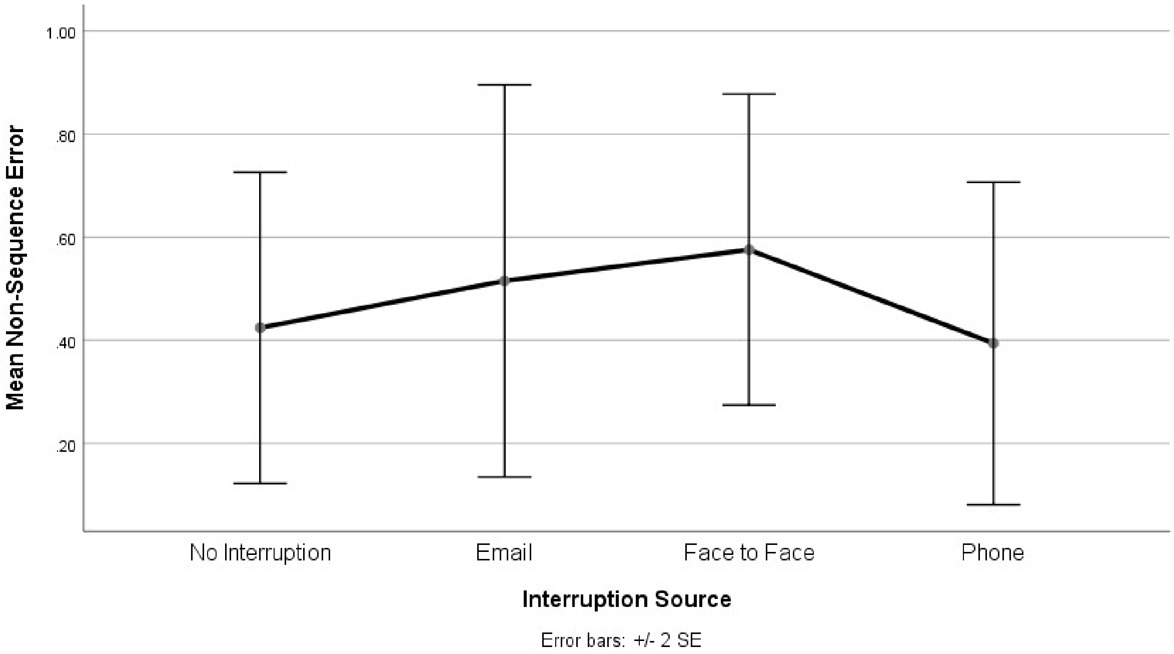


Figure 29 Mean non-sequence errors across interruption source conditions.

Interruption Source Analysis 6 - Comparison of post-interruption non-sequence errors (errors occurring directly after the interruption upon resumption of primary task) compared to no interruption (control) non-sequence errors.

A repeated measure ANOVA was used to explore whether the number of non-sequence errors significantly increased/decreased directly after resuming a primary task (post-interruption errors) across each interruption source manipulation compared to the non-sequence errors observed in the control condition. There was a partially non-significant effect of interruption source on the number of non-sequence errors, *F*(1.53, 49.26) = 3.43, MSE = .463, *p* =.052, $\eta^2_p = .097$. Despite this, it appeared that that non-sequence errors occurred more in the No Interruption condition (*M* = .424, *SE* = .867) compared to post-interruption non-sequence errors in the Email (*M* = .091, *SE* = .291), Face to Face (*M* = .212, *SE* = .415) and Phone conditions (*M* = .091, *SE* = .291) (Figure 30).

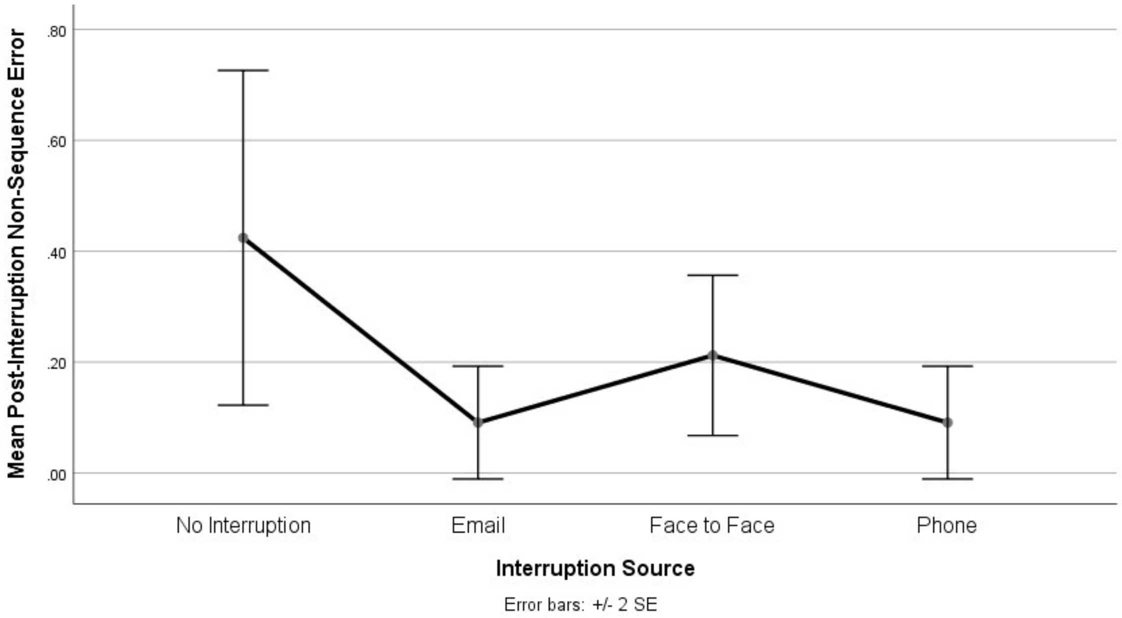


Figure 30 Post-interruption non-sequence error across interruption source conditions.

Interruption Source Analysis 7 - General effect of interruption source, CAMROSE task step, and the interaction of both on non-sequence errors.

A 4 (Interruption Source: No Interruption, Email Interruption, Face to Face Interruption, Phone Interruption) x 7 (CAMROSE Task Step: Step 1 (C), Step 2 (A), Step 3 (M), Step 4 (R), Step 5 (O), Step 6 (S), Step 7 (E)) repeated measures ANOVA was used to explore the main effect of interruption source and CAMROSE task step as well as the interacting effect on non-sequence errors. There was no significant main effect of interruption source on the number of non-sequence errors being made on each task step, $F(2.17, 69.53) = .479$, MSE = .095, $p > .05$, $\eta^2_p = .015$. There was no significant main effect of CAMROSE task step on the number of non-sequence errors being made, $F(3.07, 98.50) = 2.02$, MSE = .272, $p = >.05$, $\eta^2_p = .060$. There was no significant interaction between interruption source and CAMROSE task step on the number of non-sequence errors being made, $F(4.90, 156.78) = .345$, MSE = .284, $p >.05$, $\eta^2_p = .034$.

Interruption Source Analysis 8 - Comparison of post-interruption non-sequence errors (errors occurring directly after the interruption upon resumption of primary task) compared to no interruption (control) sequence errors through comparison of interruption source, CAMROSE task step, and the interaction of both.

A 4 (Interruption Source: No Interruption, Email Interruption, Face to Face Interruption, Phone Interruption) x 7 (CAMROSE Task Step: Step 1 (C), Step 2 (A), Step 3 (M), Step 4 (R), Step 5 (O), Step 6 (S), Step 7 (E)) repeated measures ANOVA was used to explore the main effect of interruption source and CAMROSE task step as well as the interacting effect on post-interruption non-sequence errors. A partially non-significant main effect was revealed on interruption source on the number of post-interruption non-sequence errors made on a CAMROSE task step $F(1.53, 49.26) = 3.43$, MSE = .066, $p = .052$, $\eta^2_p = .097$. There was no significant main effect of CAMROSE task step on the number of post-interruption non-sequence errors being made, $F(2.86, 91.67) = 1.38$, MSE = .086, $p > .05$, $\eta^2_p = .041$. There was also no significant interaction between interruption source and CAMROSE task step on the number on post-interruption non-sequence errors being made $F(4.63, 148.33) = 1.58$, MSE = .133, $p > .05$, $\eta^2_p = .047$.

Interruption Source Analysis 9 - General comparison of inter-action interval (time between to respond to each CAMROSE task step) across each interruption source condition.

A repeated measure analysis of variance (ANOVA) was used to test the effects of interruption source (No Interruption, Email Interruption, Face to Face Interruption, Phone Interruption) on the average time (seconds) to make a response on a task step (inter-action interval). There was a significant effect of interruption source on the inter-action interval, *F*(3, 96) = 6.63, MSE = .552, $p < .001$, $\eta^2_p = .172$. Bonferroni pairwise comparisons revealed that participants were taking significantly longer to make a response in the Email (*M* = 2.96, *SE* = 1.01), Face to Face (*M* = 2.87, *SE* = .872) and Phone (*M* = 2.87, *SE* = .934) conditions compared to the No Interruption condition (*M* = 2.24, *SE* = .800) with all *p's* <.01 (Figure 31).

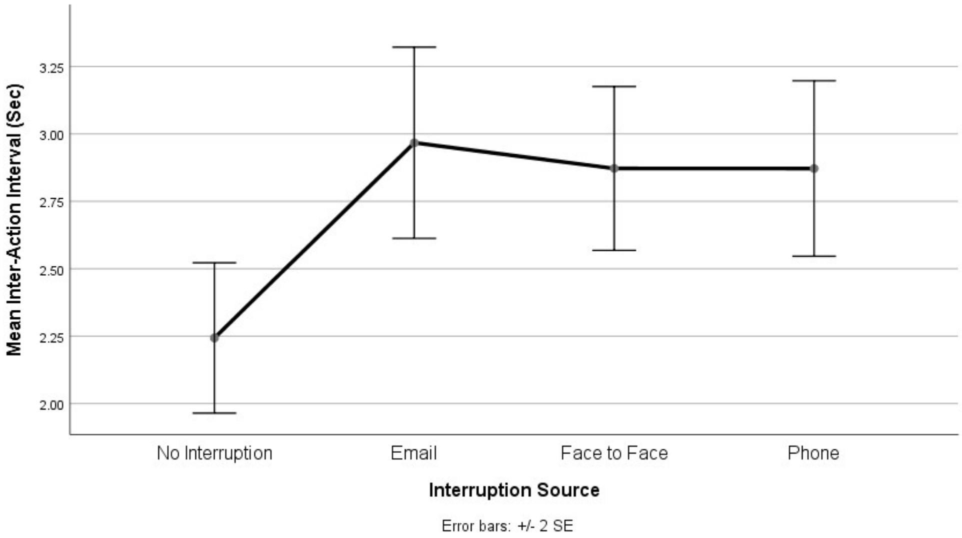


Figure 31 Comparison of inter-action interval across interruption source

Interruption Source Analysis 10 - Comparison of post-interruption resumption lag (time between end of interruption and first response back onto primary task) compared to inter-action interval.

Paired samples t-tests were used to test for differences between resumption lag and inter-action interval on each interruption source manipulation. Results indicated that resumption lag was significantly higher (*M* = 4.03, *SE* = 1.66) than inter-action interval (*M* = 2.96, *SE* = 1.01) in the Email condition *t*(32) = 7.85, *p* <.001, significantly higher (*M* = 3.38, *SE* = 1.06) than inter-action interval (*M* = 2.87, *SE* = .872) in the Face to Face condition *t*(32) = 6.64, *p* <.001, and no significantly difference between resumption lag (*M* = 2.80, *SE* = .850) than inter-action interval (*M* = 2.87, *SE* = .934) in the Phone condition *t*(32) = .812, *p* >.05 (Figure 32).

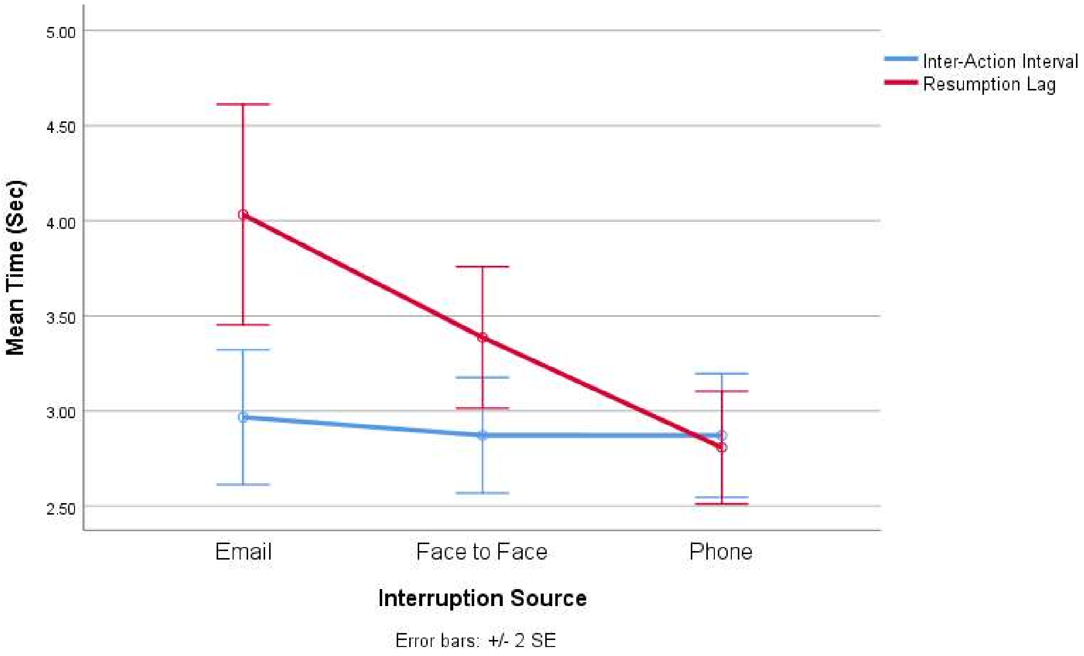


Figure 32 Comparison of inter-action interval and resumption lag across interruption source

Interruption Source Analysis 11 - Comparison of resumption lag compared to no interruption (control) inter-action interval across interruption source, CAMROSE task step, and the interaction of both.

A 4 (Interruption Complexity: No Interruption, Email Interruption, Face to Face Interruption, Phone Interruption) x 7 (CAMROSE Task Step: Step 1 (C), Step 2 (A), Step 3 (M), Step 4 (R), Step 5 (O), Step 6 (S), Step 7 (E)) repeated measures ANOVA was used to explore the main effect of interruption source and CAMROSE task step as well as the interacting effect on resumption lag (Figure 33). A significant main effect was found of interruption source on the time to resume the primary task on a CAMROSE task step $F(1.54, 49.35) = 69.63$, MSE = 46.72, $p < .001$, $\eta^2_p = .685$. Bonferroni pairwise comparisons indicated that it took longer on average to resume a task step after an interruption in the Email ($M = 8.34$, $SD = 3.52$), Face to Face ($M = 3.38$, $SD = 1.06$) and Phone ($M = 5.61$, $SD = 1.70$) conditions compared to the average time to complete the same task step in the No Interruption condition ($M = 2.24$, $SD = .800$) with all *p's* <.001. Furthermore, resumption was significantly longer in the Email condition compared to the Face to Face ($p <.001$) and Phone ($p <.01$) conditions, while resumption in the Phone condition was significantly longer than the Face to Face ($p <.001$) condition.

There was a significant main effect of CAMROSE task step on the time to resume a task after an interruption $F(6, 192) = 2.22$, MSE = 7.56, $p < .05$, $\eta^2_p = .065$. Whilst there was trend in that time to resume the primary task appeared longer on step 3 (M) ($M = 5.04$, $SD = 1.92$), step 4 (R) ($M = 5.30$, $SD = 1.77$), step 5 (O) ($M = 5.05$, $SD = 2.09$), and step 7 (E) ($M = 5.25$, $SD = 1.83$) compared to step 1 (C) ($M = 4.50$, $SD = 1.19$), step 2 (A) ($M = 4.41$, $SD = 1.93$) and step 6 (S) ($M = 4.71$, $SD = 1.86$), Bonferroni pairwise comparisons revealed that such differences were not significant. There was a partially non-significant interaction between interruption source and CAMROSE task step on resumption time *F*(7.54, 241.54) = 1.94, MSE = 17.30, p =.058, η^2_p = .057.

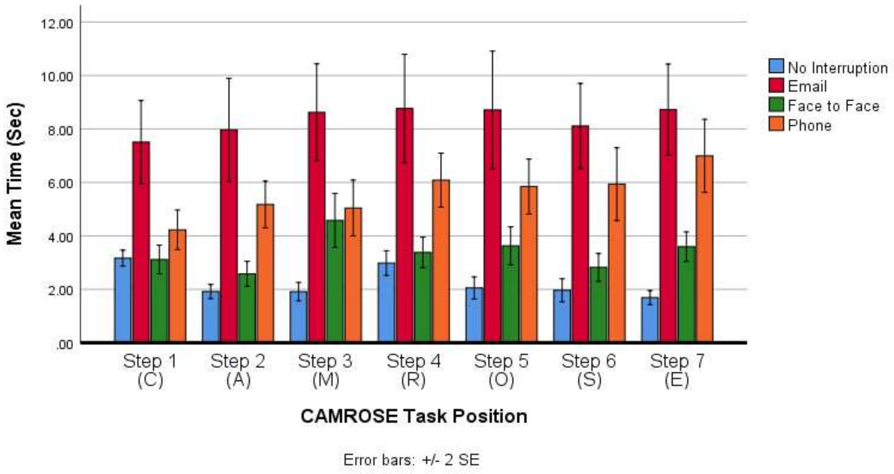


Figure 33 Resumption lag across each CAMROSE task step for each interruption source condition.

Summary

In terms of sequence errors, conditions with task interruptions, regardless of the source from which it was initiated, produced more than conditions with no interruption. This finding was consistent across all interruption sources; however, despite the fact that email interruptions had more sequence errors, they did not differ significantly from face-to-face and phone interruptions. As a result, hypothesis one was partially supported. According to hypothesis two, there was no significant difference in the number of non-sequence errors made between the no interruption and task interruption conditions. When compared to the no interruption condition, participants took significantly longer to respond in the interruption conditions regardless of the source. In the email and face-to-face conditions, the time to resume the primary task was significantly longer than the inter-action interval, but not in the phone condition. This lends support to hypothesis three. There were significantly more post interruption sequence errors when the source of interruption was an email compared to no interruption sequence errors and post interruption sequence errors when the source was face-to-face or phone. This validates hypothesis four's predictions.

The parameters of the CAMROSE task have been explored through interruption manipulations that mimic those that healthcare professionals are likely to encounter on a regular basis, including interruption complexity, frequency, and mode of communication. Traditional experimental tasks used to investigate task interruptions have provided useful information in understanding interruption effects, but the translation to clinical practise is still unclear. These studies' findings are both consistent with and distinct from those reported in previous studies. For starters, interruptions have an impact on performance in terms of the number of errors and task efficiency. However, the extent to which such declines in performance occur varies, implying that other factors are involved. One factor could be the contextual elements of the CAMROSE and interruption task. Individuals unfamiliar with contexts may perceive such interruptions as complex regardless of the number of task steps. Furthermore, the frequency of simple interruptions has a significant impact on performance and the source from which they are initiated. While context is one possible explanation, there may be other characteristics specific to the healthcare environment at work. Much of the literature on the effects of various task interruption characteristics focuses on the cognitive mediators that the previous three experiments simulated. Understanding the role of emotions and urgency on task interruptions and cognitive performance has practical implications, as both are likely to occur on a daily basis in high-emotional work environments such as healthcare.

The following experiments investigate the effects of task interruptions' emotional valance and urgency on CAMROSE task performance.

Chapter 4: Experiments 4 & 5 Explore unique healthcare characteristics of task interruptions.

Experiment 4: Interruption Complexity and Emotional Valance

Experimental Hypotheses

Emotions and cognitions may control cognitive processes like working memory and attention (Storbeck and Clore. 2007). Emotional stimuli can distract from a primary task, leaving fewer resources for task completion (Verbruggen and De Houwer. 2007). Valence and arousal are used to assess emotional stimuli (Labar and Cabeza. 2006). Interruptions affect performance both cognitively and emotionally (Mark et al., 2008; Adamczyk & Bailey, 2004; Brumby et al., 2014). Emotional task interruptions have conflicting effects on performance (Kensinger & Corkin, 2003; Levens & Phelps, 2008; Lindstrom & Bohlin, 2010). Morgan and colleagues (2015; 2017) examined how interruptions with valence affected memory recall word task performance. Since valences differ in arousal and are hard to distinguish, they also controlled for it (Kensinger, 2004). Some trials were interrupted by scenes of different valence (positive and negative) and strength (e.g., moderate and strong). Negative valence trials and longer word recall points showed greater memory impairment (i.e., higher working-memory load). Positive valence interruptions disrupted less.

Notably, in Morgan and colleagues' (2017) study, emotional scene interruptions obscured the primary task. In natural working environments, interruptions are unpredictable, but they are frequently task relevant. Other research suggests that the dissimilarity of interruption content may exaggerate the interruption effect (Speier et al., 1999), and that if the task is emotionally relevant, both negative and positive emotion has an effective and increasing effect on performance (Anderson & Phelps, 2001; Vuilleumier, 2005). The following experiment investigates the impact of emotional valanced task interruptions on performance even farther. Furthermore, in order to replicate previous findings and explore potential interacting effects, the experiment includes complexity as a variable. The hypotheses that follow are based on a review of the literature on the effects of interruption complexity and emotional valance on performance. It is predicted that interruption complexity conditions will have an impact on all performance errors except non-sequence errors when compared to the no interruption condition. As complexity increases, so will error and time deficits (*H1*). When compared to neutral valance conditions, interruptions with a high emotional valance in terms of positive and negative valance cause more post-interruption errors and longer resumption times (*H2*). On performance measures, there will be a significant interaction between interruption complexity and emotional valance (*H3*).

Method

Participants

An opportunity sampling method was used to recruit 49 different psychology students aged 18–30 years of age (M = 19.76; SD = .40). During the data coding process, 12 participants appeared to either misunderstand the experimental procedure resulting >90% inaccuracy on all dependent measures or were part of a session that experienced technical issues in the data collection and thus their data was excluded from the main data analysis. Therefore, data was analysed and is presented for N = 37. 25 participants were female and12 were male. Participants were given course credits for their participation linked to their UG BSc Psychology degree research methods training. All participants had normal-corrected vision and hearing and were English first language or highly proficient in English as a second language.

Design

The following experiment adopted a 4 x 3 repeated measures design. The first main independent variable was the amount of cognitive load the clinical interruption places upon the participant, defined as the complexity associated with completing the clinical interruption task. Complexity (and thus, cognitive load) was decided by the number of steps needed to complete the secondary interrupting task, and this had four levels: No Interruption/Control, Low Complexity/1 Step, Moderate Complexity/3 Steps, High Complexity/5 Steps. The second independent variable was the extent in which the interruption task was emotionally phrased, that is the level of valance of key words which dictated the patient's current health. Emotional valance had three levels: Neutral valanced words, Positive valanced words, and Negative valanced words. Furthermore, interruptions that occur within points of the experimental task where cognitive load is likely to be higher (mid-way through the sequence) may have more of a profound effect on performance than interruptions occurring at points where cognitive load is likely to be lower (at the beginning of the task; Altmann & Trafton, 2015). Given this, interruption position was a variable controlled for whereby interruptions were designed to occur twice on each sequential step of the primary task (CAMROSE) throughout the experiment.

Given the nature of the CAMROSE procedural primary task, several dependent variables (DV) were recorded. DV-1 was sequence errors which was decided by the incorrect step performed (e.g., a step that does not logically follow on from the previous step). DV-2 was non-sequence errors when the correct step is performed but with the wrong response (each step has two possible responses). Both DV's will supply insights into task accuracy both overall and post-interruption (e.g., errors that occur directly after an interruption upon resumption of the primary task). The post-interruption analysis will also allow for the comparison valance, as valance was balanced within each condition, which is each condition represented a complexity condition with task interruptions varying in valance within them. Timing measures (such as time to resume to primary task – resumption lag) were also recorded to measure task and resumption efficiency. DV-3 was a measure of inter-action interval (resumption lag) by recording the time taken from the end of the interruption until the first keyboard response back on the primary task (Cades et al, 2008). This will allow for the assessment in differences in disruptiveness between interruption task complexity. DV-4 was the reaction time on each step of the primary and interruption task.

Each step of the experimental task was considered as a trial (7 trials = 1 full sequence), and an experimental block had 5 sequences (1 block = 5 sequences = 35 trials). Each block represented a within-participant complexity level, so a total of 4 blocks (Total = 140 trials). During each experimental block, each sequence was continuous until all trials were completed (e.g., E will be followed by C). At the end of each experimental block, participants were given the opportunity to take a break before beginning the next block. Interruption complexity and valance was counterbalanced using the same Latin Square in previous experiments, creating 4 versions of the experiment. The same images of the routinely scheduled medicines chart occur within each experimental block, but the order of the images was randomly pre-selected using an online random sequence generator (Random.org; https://www.random.org/sequences/). Each sequential trial was interrupted at least twice throughout each block, with 5 interruptions occurring for each valance condition, equalling to 15 interruptions per experimental block (Table 18), and these occurred at the end of one trial before starting the next.

Table 18 Counterbalance for emotional valanced interruption stimuli across each task step and experimental sequence.

	Sequence 1	**Sequence 2**	**Sequence 3**	**Sequence 4**	**Sequence 5**
Step 1	Neg	No	No	Neg	No
Step 2	No	Neut	No	No	Neut
Step 3	No	Pos	Pos	No	No
Step 4	No	No	No	Neut	Pos

Step 5	Neut	No	Neg	No	No
Step 6	No	Neg	Neut	No	Neg
Step 7	Pos	No	No	Pos	No

No = No Interruption, Neut = Neutral Valance, Pos = Positive Valance, Neg = Negative Valance

Materials

The primary and interruption task used in this experiment is the CAMROSE Medication Pre-Administration Task and Clinical Decision-Making Task explained in Section 4.2.1/4.2.2. Unlike the preceding experiments, the stimuli did not change after every response, instead the same information was presented for the duration of the sequence, and only changed at the start of the next sequence. This decision was made to keep some representation of the task to a healthcare setting, that is, during the administration of medication all checks are performed on the patient at hand. Experiments were running within psychology laps on individual workstations (each separated by a partition) that held between 4-16 participants. Each workstation had a desktop PC, computer mouse and keyboard, and over-ear headphones. To respond accordingly to the interruptions, participants had a paper reference version of the clinical score chart and actions required present at their workstation.

Interruptions were started by an image of a nurse and audio recording of a clinical If-Then scenario. Both the image and audio recording varied depending upon the valance condition. Scenarios were created using words selected from the Affective Norms of English Words (ANEW; Bradley & Lang, 1999), whereby each phrase before the IF-THEN scenario would show a patient’s current condition. Words were selected from ANEW based upon valance rating (scale ratings ranged from 1-10 whereby 1 = Negative and 10 = Positive), with attempts made to control for arousal (scale ratings for arousal ranged from 1-10 whereby 1 =

Low and 10 = High). Table 16 Indicates the word choice, whilst Figure 34 Shows the corresponding image to the valance condition with example scenarios.

"To see the patient for a routine check…"

"The patient's medicine was a **success**, and they are showing **progress**…"

"The patient's medicine was **rejected**, and they are in **discomfort**…"

Figure 34 Example of nurse confederate interruptions and emotionally valanced word choices.

A small pilot study with 10 Psychology students was conducted to ensure that each of the valence conditions varied as expected, whilst arousal was kept. Participants were presented with each stimulus, both the image with the corresponding scenario and asked to rate both subjective valence and arousal. Valence scores were comparable to the means in ANEW and were significantly perceived as distinct in terms of the valance, *F*(2, 27) = 83.6, *p* <.001 with the negative stimuli being the lowest rating (M = 3.75, SE = .42), positive stimuli being the highest (M = 7.20, SE = .86), and neutral stimuli in the middle (M = 5.60, SE = .39). Furthermore, there was no significant difference between each condition in terms of arousal, *F*(2, 27) = 1.08, *p* = .35, indicating that arousal was constant across all scenarios. Reponses were made on the computer after the interruption and participants would press the 'enter' key on the keyboard once they were finished and returned to the primary task where they left off.

Table 19 Emotional word choice with associated average valance and arousal scores.

Neutral Words	**Mean Valence**	**SD Valence**	**Mean Arousal**	**SD Arousal**
Patient	5.29	1.89	4.21	2.37
Medicine	5.67	2.06	4.40	2.36
Positive Words	**Mean Valence**	**SD Valence**	**Mean Arousal**	**SD Arousal**
Success	8.29	0.93	6.11	2.65
Progress	7.73	1.34	6.02	2.58

Negative Words	**Mean Valence**	**SD Valence**	**Mean Arousal**	**SD Arousal**
Rejected	1.50	1.09	6.37	2.56
Discomfort	2.19	1.23	4.17	2.44

Procedure

Upon entering the experimental room, participants were asked to read the participant information and experimental instructions before providing informed consent to participate. The experimental instructions were also explained in detail by the researcher, expressing the importance of remembering the acronym CAMROSE and its associated responses. Participants were encouraged to ask questions regarding any elements of the primary task to ensure they fully understood what was expected. After explanation of how to perform the primary task, participants completed a short practice stage without any interruptions which consisted of 14 trials. During all the practice trials, the CAMROSE acronym and its associated responses were present to help participants learn the procedure. Again, participants were encouraged to use this as much as needed throughout the practice trials. Upon completion of the practice trials for the primary task, the researcher explained the interruption task, and participants were instructed to complete the interruption task by providing a clinical score and required response based upon the if-then scenario presented, and then to return to the primary task where they had left off. Participants were not instructed directly during the briefing that this was an interruption task but rather a secondary task in which performance on both tasks were equally important for the experiment. Participants completed another round of 14 practice trials, this time including a sample of interruptions they were expected to experience throughout the experiment phase. During this phase, participants were requested to wear the over-ear headphones provided until they had finished. The acronym and possible responses continued to be present for these practice trials as well. After the practice trials participants were once again encouraged to ask questions if they were unsure and/or complete another practice run if they wished to do so. If participants were happy to continue, before beginning, all paperwork not related to the experiment including the acronym was collected, and pens and phones were asked to be put away. Participants wore the headphones throughout the whole experiment. At the end of the main experimental phase, participants were fully debriefed. Total experimental time was approx. 60 minutes.

Results

Interruption Complexity and Emotional Valance Analysis 1 - General effects of interruption complexity on sequence errors during CAMROSE Medication Pre-Administration Task.

Firstly, complexity was explored to see if the findings were repeated from those previously reported in experiment 1. A repeated measure analysis of variance (ANOVA) was used to test the effects of interruption complexity (No Interruption, Low Complexity, Moderate Complexity, High Complexity) on the number of sequence errors made. Results indicated a significant effect of interruption complexity on the number of sequence errors being made, $F(3, 108) = 25.07$, MSE = 6.76, $p < .001$, $\eta^2_p = .411$, with participants making significantly less sequence errors in the No Interruption condition ($M = 2.29$, $SD = 2.30$) compared to the Low ($M = 5.78$, $SD = 4.08$), Moderate ($M = 6.59$, $SD = 3.96$), and High ($M = 7.00$, $SD = 4.58$) complexity conditions with all *p's* < .001. There was no significant difference in the number of sequence errors being made between the low, moderate, and high complexity conditions with all *p's* > .05, despite there being a visible trend in that as complexity is increased so is the number of sequence errors being made (Figure 35).

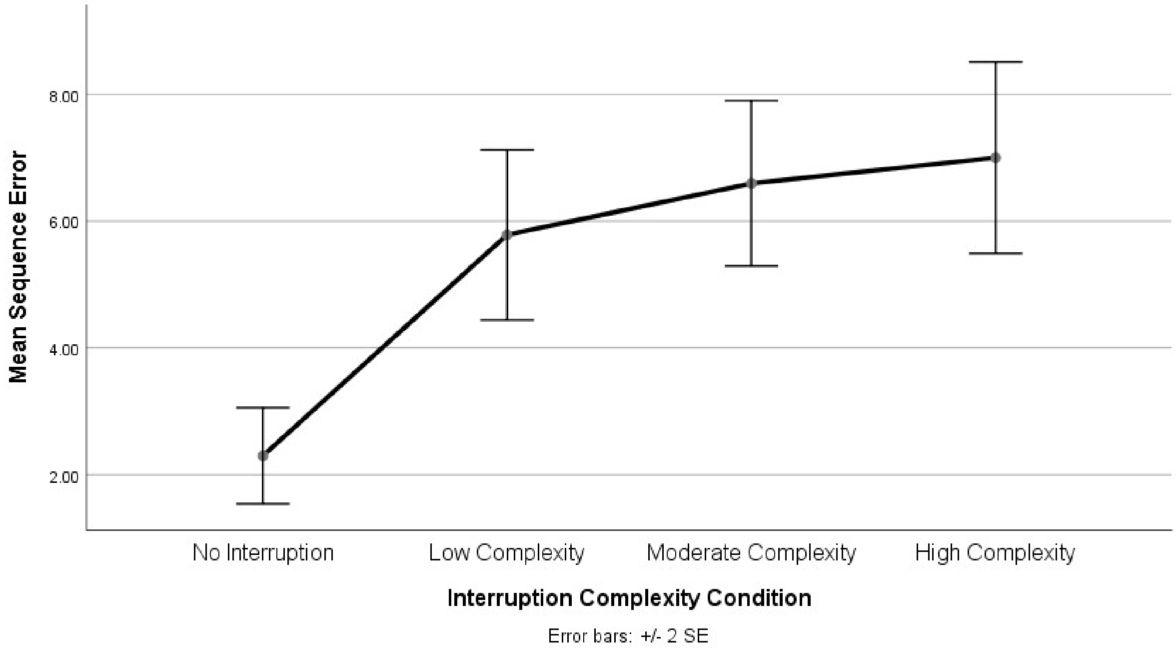


Figure 35 Mean sequence error across interruption complexity conditions for experiment 4.

Interruption Complexity and Emotional Valance Analysis 2 - A comparison of interruption complexity and emotional valance and the interaction of both through examining post-interruption sequence errors (errors occurring directly after the interruption upon resumption of primary task).

A 3 (Interruption Complexity: Low Complexity, Moderate Complexity, High Complexity) x 3 (Emotional Valance: Neutral Valance, Positive Valance, Negative Valance) repeated measures ANOVA was used to explore whether the number of post-interruption sequence errors significantly increased/decreased directly after resuming a primary task across each complexity and emotional valance manipulation along with the interacting effect of them both. Results indicated no significant main effect of interruption complexity on the number of post-interruption sequence errors being made, $F(2, 72) = .751$, MSE = .532, $p > .05$, $\eta^2_p = .020$, despite more post-interruption sequence errors being made in the High Complexity condition ($M = 1.01$, $SE = .724$) compared to the Low Complexity ($M = .937$, $SE = .723$) and Moderate Complexity ($M = .901$, $SE = .622$) conditions (Figure 40). There was a significant main effect of emotional valance on sequence errors being made $F(1.68, 60.47) = 23.69$, MSE = .545, $p < .001$, $\eta^2_p = .397$. Interestingly, Bonferroni post-hoc comparisons indicated significantly more sequence errors were being made in the positive valance condition ($M = 1.33$, $SE = .816$) compared to the Neutral Valance ($M = .847$, $SE = .660$), and Negative Valance ($M = .676$, $SE = .585$) conditions with *p's* <.001. There was no significant interaction between interruption complexity and emotional valance on the number of sequence errors being made $F(3.26, 117.57) = 1.36$, MSE = .592, $p > .05$, $\eta^2_p = .037$.

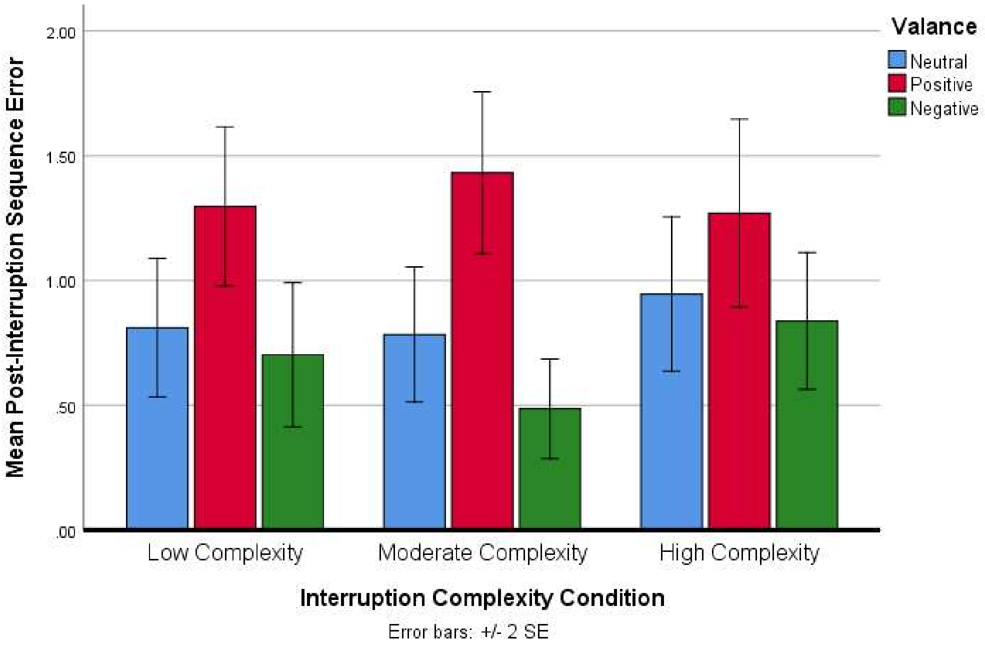


Figure 36 Mean post interruption sequence error across interruption complexity and emotional valance conditions.

Interruption Complexity and Emotional Valance Analysis 3 - General effect of interruption complexity, CAMROSE task step, and the interaction of both on sequence errors.

A 4 (Interruption Complexity: No Interruption, Low Complexity, Moderate Complexity, High Complexity) x 7 (CAMROSE Task Step: Step 1 (C), Step 2 (A), Step 3 (M), Step 4 (R), Step 5 (O), Step 6 (S), Step 7 (E)) repeated measures ANOVA was used to explore the main effect of interruption complexity and CAMROSE task step as well as the interacting effect on post-interruption sequence errors (Figure 41). A significant main effect was found for interruption complexity on the number of post-interruption sequence errors made on a CAMROSE task step $F(3, 108) = 24.70$, MSE = .974, $p < .001$, $\eta^2_p = .407$. Bonferroni post-hoc analysis revealed a liner trend in that as interruption complexity increase, so did the number of sequence errors on a CAMROSE task step. Despite such a trend, only the No Interruption condition showed significantly less sequence errors being made on a CAMROSE task step (*M* = .328, *SE* = ,329) compared to the Low (*M* = .822, *SE* = .583), Moderate (*M* = .942, *SE* = .566), and High (*M* = .996, *SE* = .659) conditions with all *p's* <.001. There were no significant differences between any of the other complexity manipulations on the number of sequence errors being made on a CAMROSE task step with p's >.05.

There was a significant main effect of CAMROSE task step on the number of sequence errors being made, $F(2.89, 104.34) = 6.08$, MSE = 4.88, $p < .01$, $\eta^2_p = .145$. Bonferroni pairwise comparisons revealed a trend in that more sequence errors appeared to occur at task step 1 (C) and task step 2 (A), with the least number of sequence errors appearing at task step 5 (O) and task step 7 (E). The sequence errors occurring on task step 1 (C) (*M* = 1.27, *SE* = .832) was significantly more than task step 5 (O) (*M* = .446, *SE* = .382, $p <.001$), task step 6 (S) (*M* = .507, *SE* = .484, $p <.01$) and task step 7 (E) (*M* = .493, *SE* = .608, $p <.01$). There were no other significant differences on the number of sequence errors being made across CAMROSE task step with remaining *p's* >.05. There was no significant interaction between interruption complexity and CAMROSE task step on the number of sequence errors being made, $F(8.98, 323.45) = 1.61$, MSE = 1.45, $p = .110$, $\eta^2_p = .043$.

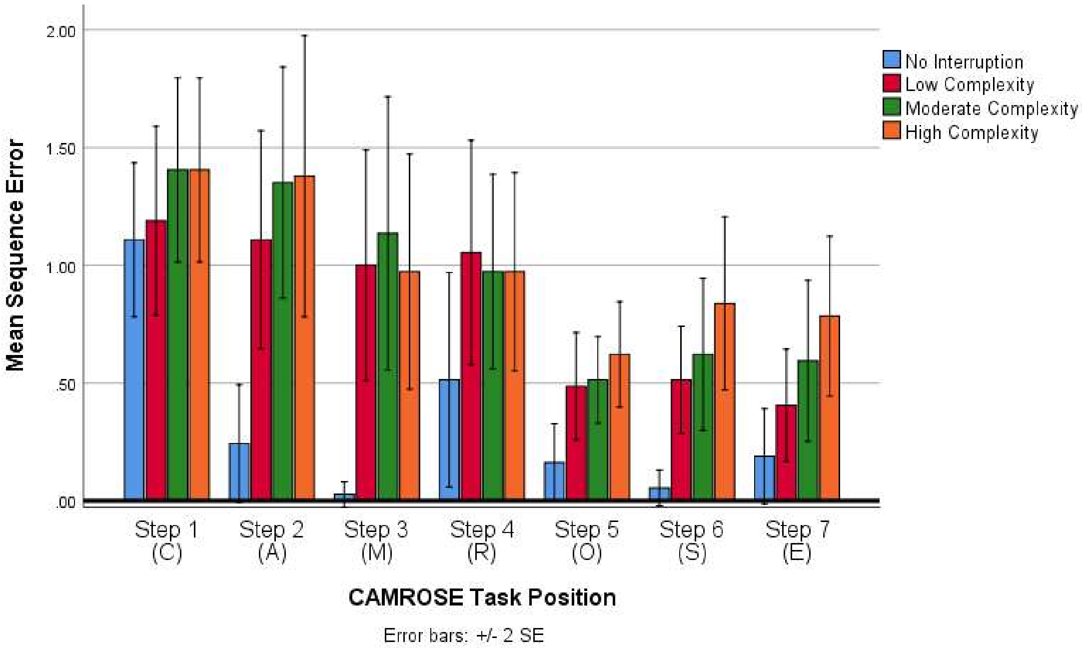


Figure 37 Sequence errors across each CAMROSE task step for each interruption complexity condition in experiment 4.

Interruption Complexity and Emotional Valance Analysis 4 - Comparison of post-interruption sequence errors (errors occurring directly after the interruption upon resumption of primary task) compared to no interruption (control) sequence errors through comparison of interruption complexity, CAMROSE task step, and the interaction of both.

A 4 (Interruption Complexity: No Interruption, Low Complexity, Moderate Complexity, High Complexity) x 7 (CAMROSE Task Step: Step 1 (C), Step 2 (A), Step 3 (M), Step 4 (R), Step 5 (O), Step 6 (S), Step 7 (E)) repeated measures ANOVA was used to explore the main effect of interruption complexity and CAMROSE task step as well as the interacting effect on post-interruption sequence errors (Figure 42). There was no significant main effect of interruption complexity on the number of post-interruption sequence errors being made on a CAMROSE task step, *F*(2.12, 76.39) = .270, MSE = .418, *p* > .05, η^2_p = .007. There was a significant main effect of CAMROSE task step on the number of post-interruption sequence errors being made, *F*(3.68, 132.56) = 11.30, MSE = .586, *p* < .001, η^2_p = .239. Bonferroni post-hoc comparisons revealed that significantly more post-interruption sequence errors were being made on CAMROSE task step 1 (C) (*M* = .493, *SE* = .319) compared to CAMROSE task step 2 (A) (*M* = .081, *SE* = .204, *p* <.001) task step 3 (M) (*M* = .257, *SE* = .246, *p* <.01), and task step 6 (S) (*M* = .270, *SE* = .308, *p* <.05). Furthermore, significantly more post-interruption sequence errors were made on CAMROSE task step 7 (E) (*M* = .574, *SE* = .436) compared to task step 2 (*M* = .081, *SE* = , *p* <.001) task step 3 (M) (*M* = .257, *SE* = , *p* <.01) and task step 6 (S) (*M* = .270, *SE* = .308, *p* <.05). Post-interruption sequence errors were significantly lower in CAMROSE task step 2 (A) (*M* = .081, *SE* = .204) compared to all other task steps, except CAMROSE task step 6 (S) with all *p's* <.05.

There was a partially significant interaction between interruption complexity and CAMROSE task position on the number of post-interruption sequence errors being made *F*(5.94, 214.09) = 7.53, MSE = .840, *p* < .001, η^2_p = .173. Bonferroni post-hoc analysis revealed significantly more sequence were occurring at task step 1 (C) in the No Interruption condition (*M* = 1.10, *SE* = .993) compared to post-interruption sequence errors on the same task step in Low (*M* = .378, *SE* = .545, *p* <.01) Moderate (*M* = .189, *SE* = .397, *p* <.001) and High (*M* = .297, *SE* = .463, *p* <.01) complexity conditions. Significantly less sequence errors were made on CAMROSE task step 3 (M) in the No Interruption condition (*M* = .027, *SE* = .164) compared to post-interruption sequence errors on the same task step in the Low (*M* = .297, *SE* = .463, *p* <.05), Moderate (*M* = .351, *SE* .483, *p* <.01) and High (*M* = .351, *SE* = .483, *p* <.01) complexity conditions. Significantly more post-interruption sequence errors were being made on CAMROSE task step 6 (S) when they occurred within the High complexity condition (*M* = .486, *SE* = .558) compared to sequence errors on the same position in the No Interruption condition (*M* = .054, *SE* = .229, *p* <.001). Significantly less sequence errors were also apparent on CAMROSE task step 7 (E) when they occurred in the No Interruption condition (*M* = .189, *SE* .616) compared to post-interruption sequence errors on the same task step in the Low (*M* = .648, *SE* = .587, *p* <.01), Moderate (*M* = .783, *SE* = .583, *p* <.001), and High (*M* = .675, *SE* = .668, *p* <.01) complexity conditions.

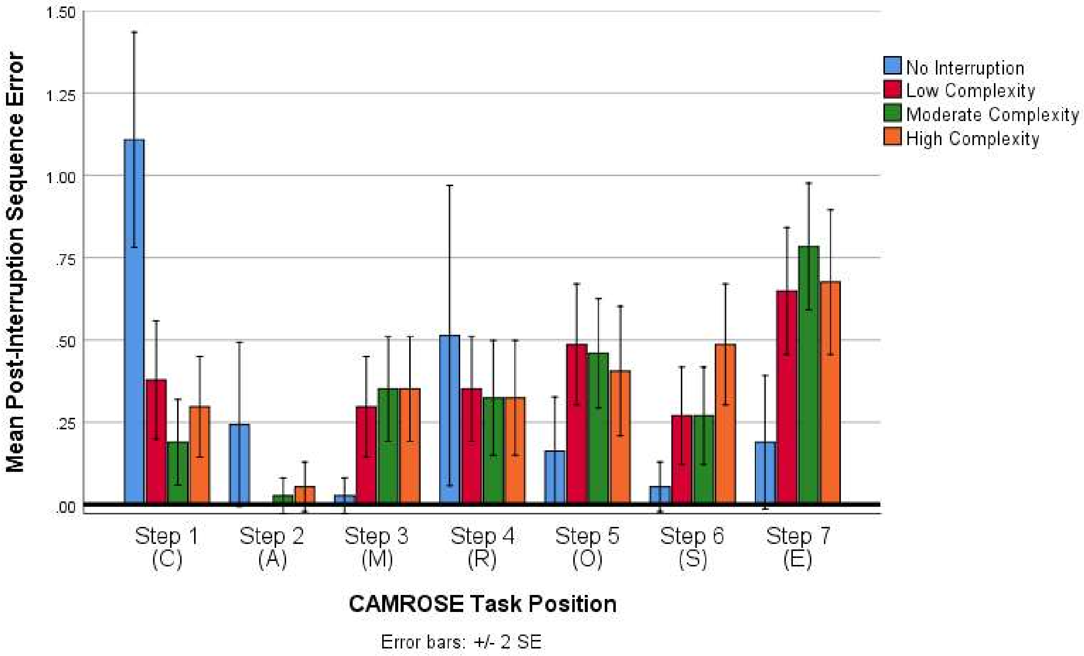


Figure 38 Post interruption sequence errors across each CAMROSE task step for each interruption complexity condition in experiment 4.

Interruption Complexity and Emotional Valance Analysis 5 - General effects of interruption complexity on non-sequence errors during CAMROSE Medication Pre-Administration Task

A repeated measure analysis of variance (ANOVA) was used to test the effects of interruption complexity (No Interruption, Low Complexity, Moderate Complexity, High Complexity) on the number of non-sequence errors made. Results indicated there was no significant effect of interruption complexity on the number of non-sequence errors being made, *F*(3, 108) = .803, MSE = .729, *p* = .495, η^2_p = .022. Despite such finding there did appear to be some unusual trends in the data (Figure 43), with the most non-sequence errors occurring in the No Interruption condition (M = 1.35, SE = 1.31) and the least in the Moderate Complexity condition (M = 1.05, SE = 1.02).

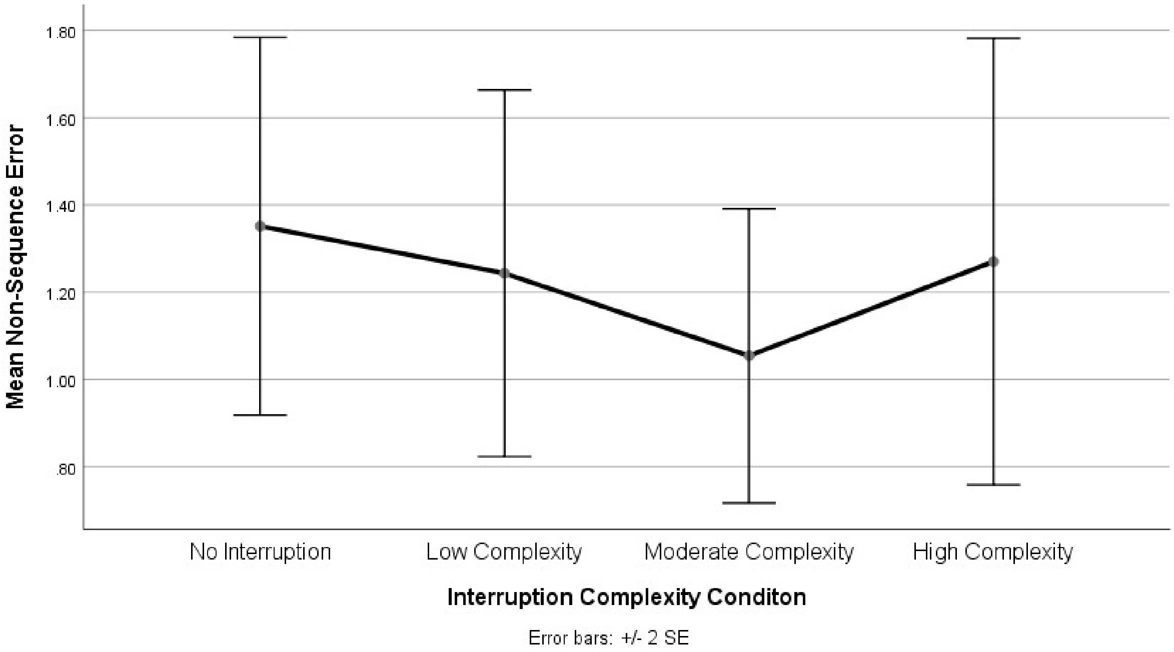


Figure 39 Mean non-sequence errors across interruption complexity conditions in experiment 4.

Interruption Complexity and Emotional Valance Analysis 6 - A comparison of interruption complexity and emotional valance and the interaction of both through examining post-interruption non-sequence errors (errors occurring directly after the interruption upon resumption of primary task).

A 3 (Interruption Complexity: Low Complexity, Moderate Complexity, High Complexity) x 3 (Emotional Valance: Neutral Valance, Positive Valance, Negative Valance) repeated measures ANOVA was used to explore whether the number of post-interruption non-sequence errors significantly increased/decreased directly after resuming a primary task across each complexity and emotional valance manipulation along with the interacting effect of them both. There was no significant main effect of interruption complexity on the number of non-sequence errors being made, $F(1.80, 64.85) = .426$, MSE = .125, $p > .05$, $\eta^2_p = .012$, no significant main effect of emotional valance on post-interruption non-sequence errors, $F(1.94, 69.96) = .124$, MSE = .174, $p > .05$, $\eta^2_p = .003$, and no significant interaction between interruption complexity and emotional valance on post-interruption non-sequence errors $F(3.62, 130.38) = .171$, MSE = .136, $p > .05$, $\eta^2_p = .005$.

Interruption Complexity and Emotional Valance Analysis 7 - General effect of interruption complexity, CAMROSE task step, and the interaction of both on non-sequence errors.

A 4 (Interruption Complexity: No Interruption, Low Complexity, Moderate Complexity, High Complexity) x 7 (CAMROSE Task Step: Step 1 (C), Step 2 (A), Step 3 (M), Step 4 (R), Step 5 (O), Step 6 (S), Step 7 (E)) repeated measures ANOVA was used to explore the main effect of interruption complexity and CAMROSE task step as well as the interacting effect on non-sequence errors (Figure 44). There was no significant main effect of interruption complexity on the number of non-sequence errors being made on each task step, $F(3, 108) = .1.41$, MSE = .112, $p > .05$, $\eta^2_p = .038$. There was a significant main effect of CAMROSE task step on the number of non-sequence errors being made, $F(1.76, 63.43) = 10.26$, MSE = 3.14, $p = <.001$, $\eta^2_p = .222$. Bonferroni pairwise comparisons revealed that significantly more non-sequence errors were made on CAMROSE task step 4 (R) ($M = .730$, $SE = 1.03$) compared to CAMROSE task step 2 (A) ($M = .020$, $SE = .090$, $p < .01$), CAMROSE task step 3 (M) ($M = .101$, $SE = .325$, $p < .05$), CAMROSE task step 5 (O) ($M = .027$, $SE = .098$, $p <.01$) CAMROSE task step 6 (S) ($M = .128$, $SE = .209$, $p <.05$) and CAMROSE task step 7 (E) ($M = .034$, $SE = .086$, $p <.01$). There were no other significant differences in the number of non-sequence errors being made on any other CAMROSE task step with all *p's* >.05. There was no significant interaction between interruption complexity and CAMROSE task step on the number of non-sequence errors being made, $F(6.36, 229.24) = 1.47$, MSE = .357, $p >.05$, $\eta^2_p = .039$.

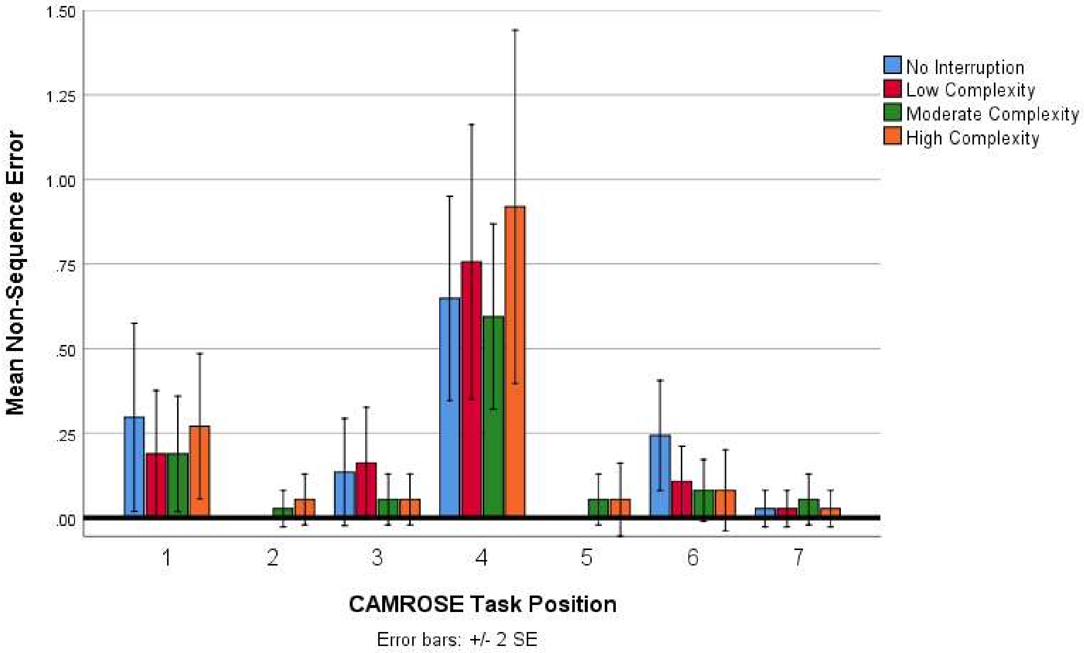


Figure 40 Non-sequence errors across each CAMROSE task step for each interruption complexity condition in experiment 4.

Interruption Complexity and Emotional Valance Analysis 8 - Comparison of post-interruption non-sequence errors (errors occurring directly after the interruption upon resumption of primary task) compared to no interruption (control) sequence errors through comparison of interruption complexity, CAMROSE task step, and the interaction of both.

A 4 (Interruption Complexity: No Interruption, Low Complexity, Moderate Complexity, High Complexity) x 7 (CAMROSE Task Step: Step 1 (C), Step 2 (A), Step 3 (M), Step 4 (R), Step 5 (O), Step 6 (S), Step 7 (E)) repeated measures ANOVA was used to explore the main effect of interruption complexity and CAMROSE task step as well as the interacting effect on post-interruption non-sequence errors (Figure 45). A significant main effect was revealed across interruption complexity on the number of post-interruption non-sequence errors made on a CAMROSE task step *F*(2.187, 78.73) = 14.39, MSE = .114, $p < .001$, η^2_p = .286. Bonferroni pairwise comparisons indicate that significantly more non-sequence errors were being made in the No Interruption condition (*M* =.193, *SE* = .188) compared to post-interruption non-sequence errors in the Low (*M* = .069, *SE* = .098, $p <.01$), Moderate (*M* = .050, SE = .076, $p <.001$), and High (*M* = .054, *SE* = .102, $p <.001$) complexity conditions. There was no other significant difference with all *p's* >.05.

There was a significant main effect of CAMROSE task step on the number of post-interruption non-sequence errors being made, *F*(3.79, 136.57) = 5.10, MSE = .208, $p <.01$, η^2_p = .124. Bonferroni post-hoc analysis revealed that significantly more non-sequence errors were being made on CAMROSE task step 4 (R) (*M* = .223, *SE* = .281) compared to CAMROSE task step 2 (A) (*M* = .014, *SE* = .057, $p <.01$), CAMROSE task step 5 (O) (*M* = .061, *SE* = .123, $p <.05$) and CAMROSE task step 7 (E) (*M* = .041, *SE* = .110, $p <.05$). There was no other significant difference with all *p's* >.05.

There was a significant interaction between interruption complexity and CAMROSE task step on the number on post-interruption non-sequence errors being made *F*(5.18, 186.56) = 4.53, MSE = .384, $p < .01$, η^2_p = .112. It was revealed in the Bonferroni post-hoc analyses that significantly more non-sequence errors were made on CAMROSE task step 4 (R) in the No Interruption condition (*M* = .648, *SE* = .919) compared to post-interruption non-sequence errors on the same task step in the Low (*M* = .162, *SE* = .373), Moderate (*M* = .027, *SE* = .164) and High (*M* = .054, *SE* = .229) complexity conditions with all *p's* <.01. There was no other significant difference with all *p's* >.05.

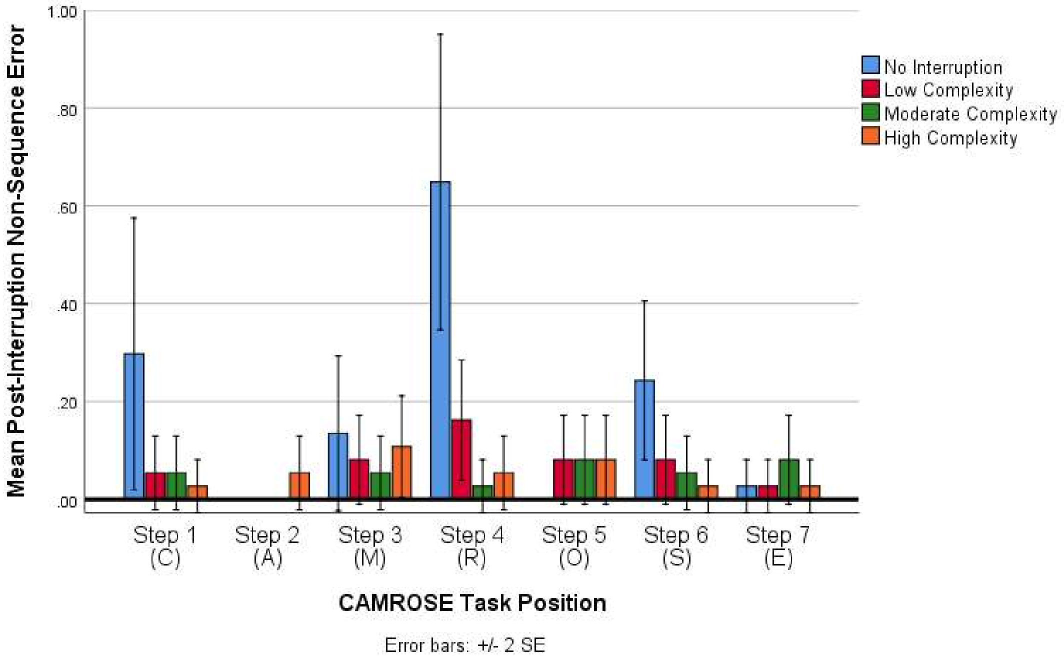


Figure 41 Post interruption non-sequence errors across each CAMROSE task step for each interruption complexity condition in experiment 4.

Interruption Complexity and Emotional Valance Analysis 9 - General comparison of inter-action interval (time between to respond to each CAMROSE task step) across each interruption complexity condition.

A repeated measure analysis of variance (ANOVA) was used to test the effects of interruption complexity (No Interruption, Low Complexity, Moderate Complexity, High Complexity) on the number of the average time (seconds) to make a response on a task step (inter-action interval). There was no significant effect of interruption complexity on the inter-action interval, $F(3, 108) = 2.26$, MSE = .266, $p = .091$, $\eta^2_p = .059$. Despite the non-significant finding, inter-action intervals did appear to be longer in the interruption complexity conditions with High complexity (M = 2.33, SE = .534) taking the most time and the No Interruption condition taking the least time (M = 2.05, SE = .831, Figure 46).

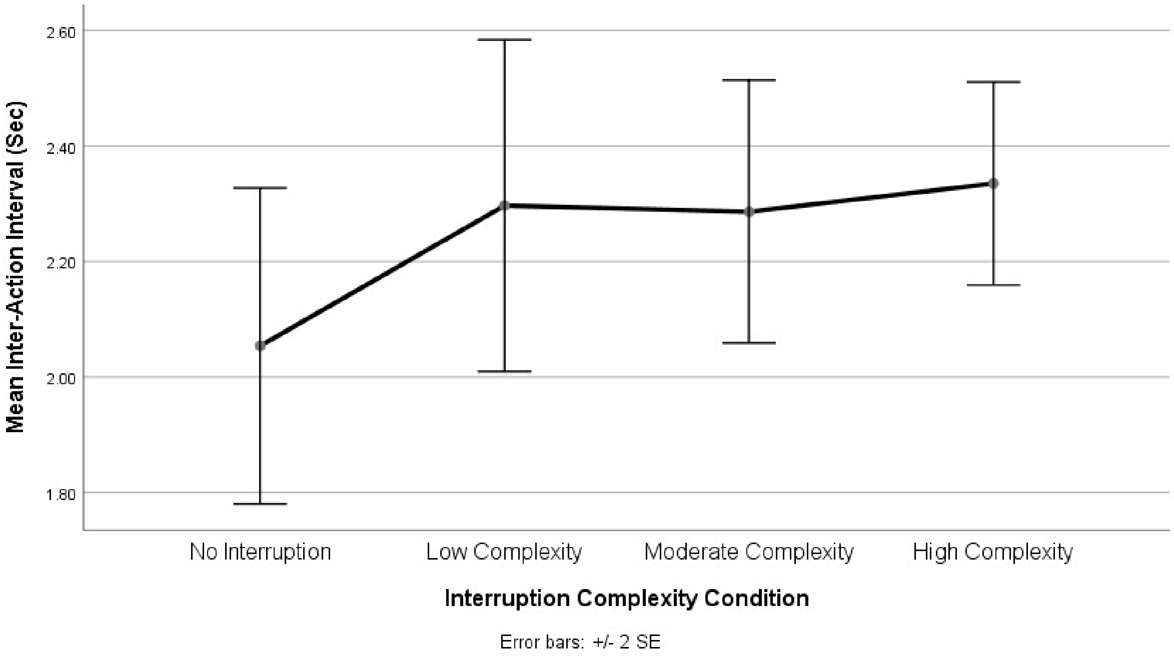


Figure 42 Comparison of inter-action interval across interruption complexity in experiment 4.

Interruption Complexity and Emotional Valance Analysis 10 - Comparison of post-interruption resumption lag (time between end of interruption and first response back onto primary task) compared to inter-action interval for complexity and emotional valance.

A 3 (Interruption Complexity: Low Complexity, Moderate Complexity and High Complexity) x 3 (Emotional Valance: Neutral, Positive and Negative) within participants ANOVA was used to explore the effects of complexity, emotional valance, and interaction of the two on resumption lag (Figure 43). There was no significant main effect of interruption complexity on resumption lag, *F*(1.63, 58.87) = .023, MSE = 1.45, p >.05, $\eta^2_p = .001$. There was a significant main effect of emotion valance on the time to resume the primary task, *F*(1.70, 61.30) = 9.41, MSE = .935, p <.01, $\eta^2_p = .207$. Bonferroni post-hoc analysis revealed that both Neutral (*M* = 2.47, *SE* = .751) and Positive (*M* = 2.67, *SE* = 1.02) valanced conditions took longer to resume the primary task after an interruption compared to the Negative valanced condition (*M* = 2.16, *SE* = .670) with *p's* <.01. There was no significant interaction between interruption complexity and emotional valance on resumption lag, *F*(2.23, 80.34) = 2.87, MSE = 1.10, p >.05, $\eta^2_p = .074$.

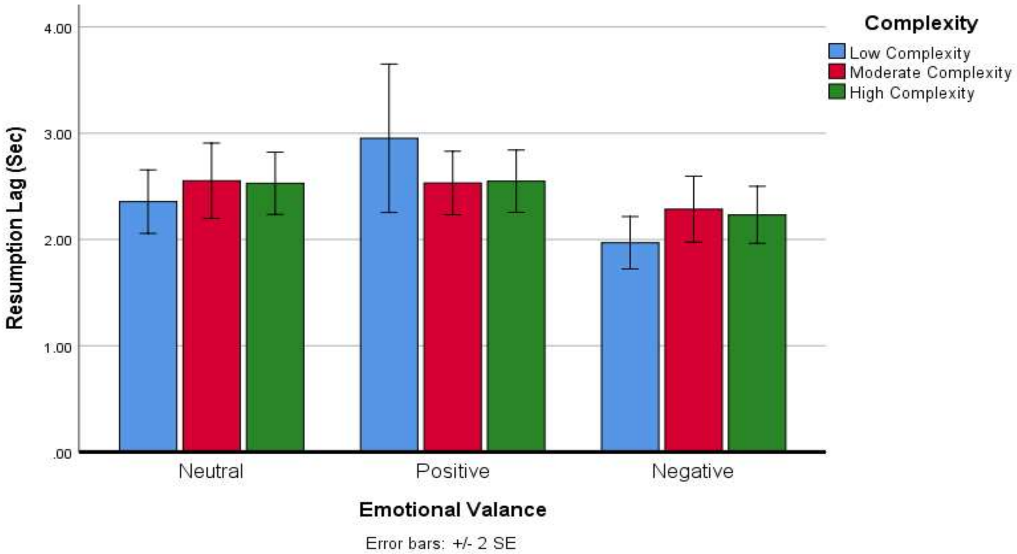


Figure 43 Comparison of resumption lag across interruption complexity and emotional valance.

Paired samples t-tests were used to test for differences between resumption lag and inter-action interval on each complexity and emotional valance manipulation. For the Low Complexity condition, results indicated that there was no significant difference in the average inter-action interval (*M* = 2.29, *SE* = .872) compared to resumption lag for Neutral valanced interruptions (*M* = 2.35, *SE* = .910), *t*(36) = .576, *p* >.05. Resumption lag for Positive valanced interruptions were significantly higher (*M* = 2.95, *SE* = 2.12) compared to the average inter-action interval *t*(36) = 2.68, *p* <.01. However, resumption lag for Negative valanced interruptions were significantly lower (*M* = 1.96, *SE* = .749) compared to the average inter-action interval *t*(36) = 4.47, *p* <.001 (Figure 44).

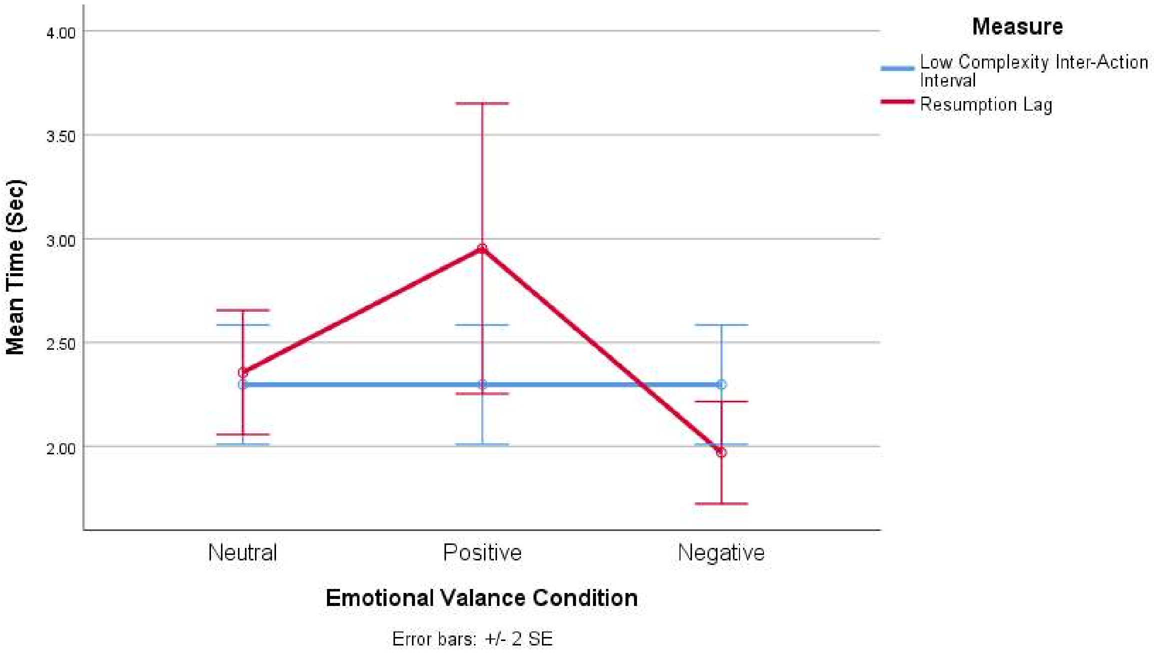


Figure 44 Comparison of inter-action interval and resumption lag across emotional valanced interruptions in low complex conditions.

In the Moderate Complexity condition, post-interruption resumption lag was significantly longer in the neutral condition (*M* = 2.55, *SE* = 1.07) compared to the average interaction-interval (*M* = 2.28, *SE* = .691) *t*(36) = 2.40, *p* <.05. The same significant trend was also present in the positive condition (*M* = 2.53, *SE* = 2.28) *t*(36) = 2.14, *p* <.05, however there was no significant difference between the resumption lag in the negative condition (*M* = 2.28, *SE* 9.42) compared to the average inter-action interval, *t*(36) = .013, *p* >.05 (Figure 45).

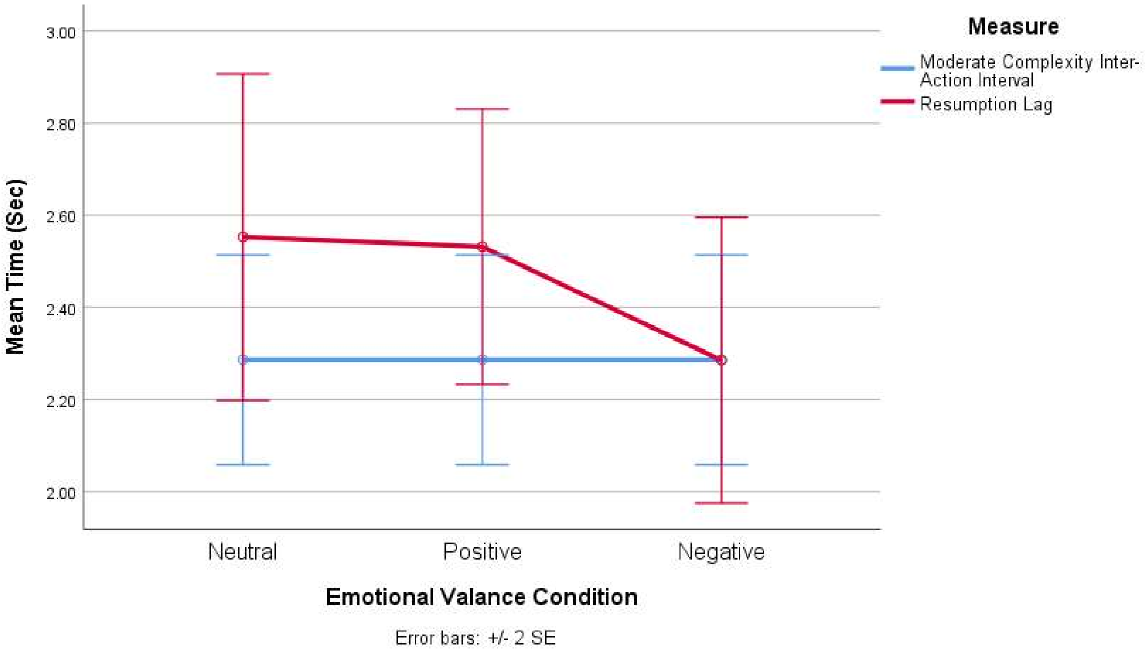


Figure 45 Comparison of inter-action interval and resumption lag across emotional valanced interruptions in moderate complex conditions.

In the High Complexity condition there was no significant difference between the average inter-action interval (*M* = 2.33, *SE* = .534) and resumption lag in the negative condition (*M* = 2.23, *SE* = .816) *t*(36) = 1.052, *p* >.05. However, both the neutral resumption lag (*M* = 2.52, *SE* = .890) *t*(36) = 1.93, *p* <.05 and positive resumption lag (*M* = 2.54, *SE* = .893) *t*(36) = 2.06, *p* <.05 were significantly longer than the average inter-action interval (Figure 46).

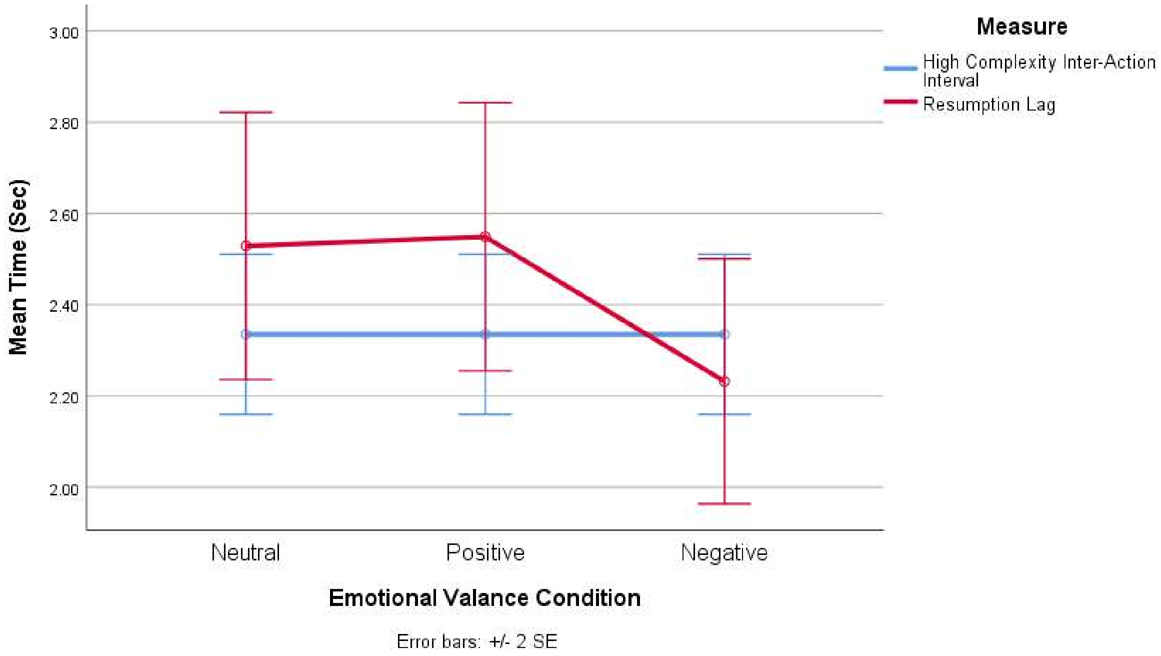


Figure 46 Comparison of inter-action interval and resumption lag across emotional valanced interruptions in high complex conditions.

Analysis 11 - Comparison of resumption lag compared to no interruption (control) inter-action interval across interruption complexity, CAMROSE task step, and the interaction of both.

A 4 (Interruption Complexity: No Interruption, Low Complexity, Moderate Complexity, High Complexity) x 7 (CAMROSE Task Step: Step 1 (C), Step 2 (A), Step 3 (M), Step 4 (R), Step 5 (O), Step 6 (S), Step 7 (E)) repeated measures ANOVA was used to explore the main effect of interruption complexity and CAMROSE task step as well as the interacting effect on resumption lag (Figure 47).

A significant main effect was found on interruption complexity step $F(2.30, 82.98) = 55.10$, MSE = 12.73, $p < .001$, $\eta^2_p = .605$. Bonferroni pairwise comparisons indicated that it took longer to resume a task step after an interruption in the Low Complexity ($M = 4.83$, $SD = 2.20$), Moderate Complexity ($M = 4.80$, $SD = 1.50$) and High Complexity ($M = 4.71$, $SD = 1.42$) conditions compared to the average time to complete the same task step in the No Interruption condition ($M = 1.90$, $SD = .707$) with all *p's* <.001.

There was a significant main effect of task step on the time to resume a task after an interruption $F(4.09, 147.44) = 5.62$, MSE = 9.17, $p < .001$, $\eta^2_p = .135$. Bonferroni post-hoc analysis revealed that significantly more time was needed to respond to CAMROSE task step 1 (C) ($M = 4.78$, $SD = 1.57$) compared to CAMROSE task step 2 (A) ($M = 3.47$, $SD = 1.11$, $p < .001$), CAMROSE task step 6 (S) ($M = 3.52$, $SD = 1.38$, $p < .001$) and CAMROSE task step 7 (E) ($M = 3.88$, $SD = 2.00$, $p < .05$). Furthermore, it took significantly longer to make a response on CAMROSE task step 4 (R) ($M = 4.54$, $SD = 2.09$) compared to CAMROSE task step 2 (A) ($p < .05$) and CAMROSE task step 6 (E) ($p < .01$). There was no significant interaction between interruption complexity and CAMROSE task step on resumption time $F(5.24, 188.85) = 1.94$, MSE = 19.39, $p > .05$, $\eta^2_p = .051$.

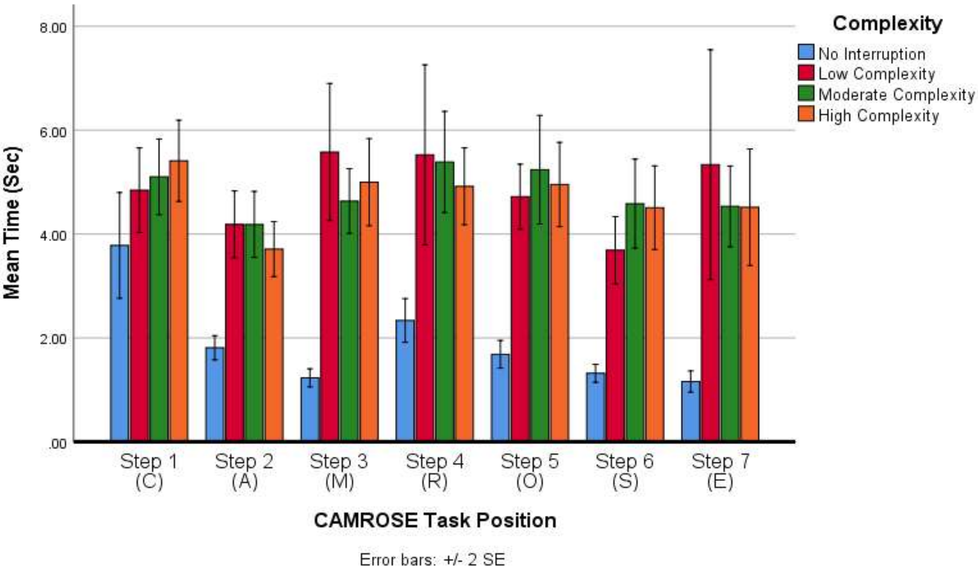


Figure 47 Comparison of inter-action interval and resumption lag across interruption complexity conditions in experiment 4.

Summary

Similar to experiment one, there were significantly more sequence errors being made on interruption conditions compared to the no interruption condition. However, whilst there was a trend in that as complexity increased so did the number of sequence errors, there was no significant difference between the low, medium and complex conditions Hypotheses one, which stated that there would be significant differences across complexity manipulations was therefore only partially supported.

In relation to predictions made for the effects of emotional valance on post interruption sequence errors, emotional valance had a significant effect. Interestingly, participants made significantly more post interruption sequence errors when the interruption was positive valanced compared to negative or neutral partially supporting hypothesis two. There was no significant interaction between interruption complexity and emotional valance on post interruption sequence errors meaning hypothesis three was partially supported. There were no significant effect or interaction of interruption complexity and emotional valance on post interruption non-sequence errors. These results do not align perfectly with what the literature has suggested. Other studies have found that if the task is emotionally significant, both negative and positive emotion have an effective and increasing effect on performance, and that the dissimilarity of interruption content may amplify the interruption effect (Speier et al., 1999). (Anderson & Phelps, 2001; Vuilleumier, 2005). While it could be argued that any emotional cue would be helpful in this study due to the healthcare setting, such a conclusion would lead one to expect no effect of emotional valance on performance, which was not found. Perhaps other factors (such as urgency) are more significant than shifts in emotional valence in determining importance.

Despite a general trend of responses taking longer as complexity increased, there was no statistically significant difference between the complexity interruption and no interruption condition in terms of the inter-interaction interval. Time to resume the primary task did not significantly vary across interruption complexity conditions. However, there were substantial differences in the time required to return to a primary task after an interruption across the three emotional valance conditions: negative, neutral, and positive.

Significant differences were discovered between the average inter-action interval and the resumption time for different levels of complexity. Time to resume a primary task after a positive valanced interruption was significantly longer than the average inter-interaction interval, even though the interruption was of low complexity. On the other hand, the resumption time was significantly shorter than the average inter-interaction interval for negative valanced interruptions. When dealing with a moderately complex interruption, it takes noticeably more time to get back on track with the primary task than during the typical inter-interaction interval, which occurs when interruptions are either neutral or positively valanced. For interruptions with a negative valence, there was no difference in reaction time. Similar results were seen in the high complexity interruption conditions, where resumption time was significantly longer than the average inter-interaction interval when interruptions were neutral or positive but not when negative.

Experiment 5: Interruption Urgency and Emotional Valance

Experimental Hypotheses

In the healthcare setting, the urgency of an interruption may be defined as an essential but time-sensitive task. This means that healthcare workers are only given a limited amount of time to complete the secondary task before they are required to return to the primary task, regardless of whether they were able to do so without interruption. This can lead to failure-stress if participants aren't given enough time to finish the secondary task before returning to the primary task. The effects of failure-stress on task performance have been well-documented, with studies showing that failure-stress decreases memory retention and increases error rates when recalling nonsensical words. Researchers have found that working under time constraints impairs decision making. Participants reported having a more difficult time locating and processing relevant data as the cause (Benbasat and Dexter, 1985). Therefore, according to the first hypothesis (H1), interruption urgency conditions will influence performance errors across the board with the exception of non-sequence errors. As the stakes become higher, so do the opportunities for mistakes and delays. Based on the results of experiment 4, it can be hypothesised that compared to neutral valance conditions, more errors and longer resumption times will occur in response to interruptions with strong positive and negative emotional valance. It is expected that there will be a significant interaction between interruption urgency and emotional valance on performance measures (H3).

Method

Participants

An opportunity sampling method was used to recruit 33 psychology students aged 18–30 years of age (M = 19.39; SD = .78). During the data coding process, 1 participant appeared to misunderstand the experimental procedure resulting >90% inaccuracy on all dependent measures and thus their data was excluded from the main data analysis. Therefore, data was analysed and is presented for N = 32. 26 participants were female, and six were male. Participants were given course credits for their participation linked to their UG BSc Psychology degree research methods training. All participants had normal-corrected vision and hearing and were English first language or highly proficient in English as a second language.

Design

The following experiment adopted a 3 x 3 repeated measures design. The first main independent variable was the urgency of the task interruption which was dictated by both the time constraints placed on completing the interruption task and signalling of an urgency through colour of text. Urgency had 3 levels: No Interruption (control), Non-Urgent Interruption (standard black text and no time constraints on completing task), and Urgent Interruption (red text, and time constraint on completing interruption task). When completing the Urgent condition participants had 7.9 seconds to complete the interruption task. Participants were also not able to return to the primary task until after this time, in which they would do so automatically regardless of whether they had completed the secondary task or not. The time was decided based upon 2/3 of the average time taken to complete an interruption in the low complexity condition of Experiment 1 (as all interruptions in this experiment were of low complexity). This ensured the interruption time was controlled for and consistent across all participants.

The second independent variable was the extent in which the interruption task was emotionally phrased, that is the level of valance of key words which dictated the patient's current health. Emotional valance had three levels which reflected the words used to initiate the interruption: Neutral valanced words, Positive valanced words, and Negative valanced words. The same words were used from Experiment 4. Furthermore, interruptions that occur within points of the experimental task where cognitive load is likely to be higher (mid-way through the sequence) may have more of a profound effect on performance than interruptions occurring at points where cognitive load is likely to be lower (at the beginning of the task; Altmann & Trafton, 2015). Given this, interruption position was a variable controlled for whereby interruptions were designed to occur twice on each sequential step of the primary task (CAMROSE) throughout the experiment. Whilst interruption position is not a main variable, it is a variable that will be considered when exploring post-interruption effects as it will provide further insight into individual task steps.

Given the nature of the CAMROSE procedural primary task, several dependent variables (DV) were recorded. DV-1 was sequence errors which was determined by the incorrect step performed (e.g., a step that does not logically follow on from the previous step). DV-2 was non-sequence errors when the correct step is performed but with the wrong response (each step has two possible responses). Both DV's will provide insights into task accuracy both overall and post-interruption (e.g., errors that occur directly after an interruption upon resumption of the primary task). The post-interruption analysis will also allow for the comparison valance, as valance was balanced within each condition, which is each condition represented a complexity condition with task interruptions varying in valance within them. Timing measures (such as time to resume to primary task – resumption lag) were also recorded to measure task and resumption efficiency. DV-3 was a measure of inter-action interval (resumption lag) by recording the time taken from the end of the interruption until the first keyboard response back on the primary task (Cades et al, 2008). This will allow for the assessment in differences in disruptiveness between interruption task complexity. DV-4 was the reaction time on each step of the primary and interruption task.

Each step of the experimental task was considered as a trial (7 trials = 1 full sequence), and an experimental block contained 5 sequences (1 block = 5 sequences = 35 trials). Each block represented a within-participant urgency level, so a total of 3 blocks (Total = 105 trials). During each experimental block, each sequence was continuous until all trials were completed (e.g., E will be followed by C). At the end of each experimental block, participants were given the opportunity to take a break before beginning the next block. Interruption urgency and valance was counterbalanced using a Latin Square, creating 3 versions of the experiment. The same images of the routinely scheduled medicines chart occur within each experimental block, but the order of the images was randomly pre-selected using an online random sequence generator (Random.org; https://www.random.org/sequences/). Each sequential trial was interrupted at least twice throughout each block, with 5 interruptions occurring for each valance condition, equalling to 15 interruptions per experimental block and these occurred at the end of one trial before starting the next.

Materials

The primary and interruption task used in this experiment is the CAMROSE Medication Pre-Administration Task and Clinical Decision-Making Task explained previously. How the stimuli were presented is the same as that in Experiment 4, the stimuli did not change after every response, instead the same information was presented for the duration of the sequence, and only changed at the start of the next sequence. Experiments were running within psychology laps on individual workstations (each separated by a partition) that held between 4-16 participants. Each workstation had a desktop PC, computer mouse and keyboard, and over-ear headphones. To respond accordingly to the interruptions, participants had a paper reference version of the clinical score chart and actions required present at their workstation. Interruptions were initiated by an image of a nurse and audio recording of a clinical If-Then scenario. The same valance scenarios were used as Experiment 4.

Procedure

Upon entering the experimental room, participants were asked to read the participant information and experimental instructions before providing informed consent to participate. The experimental instructions were also explained in detail by the researcher, expressing the importance of remembering the acronym CAMROSE and its associated responses. Participants were encouraged to ask questions regarding any elements of the primary task to ensure they fully understood what was expected. After explanation of how to perform the primary task, participants completed a short practice stage without any interruptions which consisted of 14 trials. During all the practice trials, the CAMROSE acronym and its associated responses were present to help participants learn the procedure. Again, participants were encouraged to use this as much as needed throughout the practice trials. Upon completion of the practice trials for the primary task, the researcher explained the interruption task, and participants were instructed to complete the interruption task by providing a clinical score and required response based upon the if-then scenario presented, and then to return to the primary task where they had left off. Participants were not instructed directly during the briefing that this was an interruption task but rather a secondary task in which performance on both tasks were equally important for the experiment. Participants completed another round of 14 practice trials, this time including a sample of interruptions they were expected to experience throughout the experiment phase. During this phase, participants were requested to wear the over-ear headphones provided until they had finished.

The acronym and possible responses continued to be present for these practice trials as well. After the practice trials participants were once again encouraged to ask questions if they were unsure and/or complete another practice run if they wished to do so. If participants were happy to continue, before beginning, all paperwork not related to the experiment including the acronym was collected, and pens and phones were asked to be put away. Participants wore the headphones throughout the whole experiment. At the end of the main experimental phase, participants were fully debriefed. Total experimental time was approx. 60 minutes.

Results

Interruption Urgency and Emotional Valance Analysis 1 - General effects of interruption urgency on sequence errors during CAMROSE Medication Pre-Administration Task.

A repeated measure analysis of variance (ANOVA) was used to evaluate the effects of interruption urgency (No Interruption, Non-Urgent, Urgent) on the number of sequence errors made. Results indicated a significant effect of interruption urgency on the number of sequence errors being made, $F(2, 62) = 62.14$, MSE = 12.89, $p < .001$, $\eta^2_p = .667$, with participants making significantly less sequence errors in the No Interruption condition ($M = 3.37$, $SD = 4.54$) compared to the Non-Urgent ($M = 10.56$, $SD = 5.25$), and Urgent ($M = 13.00$, $SD = 5.88$) conditions with all *p's* < .001. Furthermore, there was significantly more sequence errors being made in the Urgent condition compared to the non-Urgent condition $p <.05$ (Figure 48).

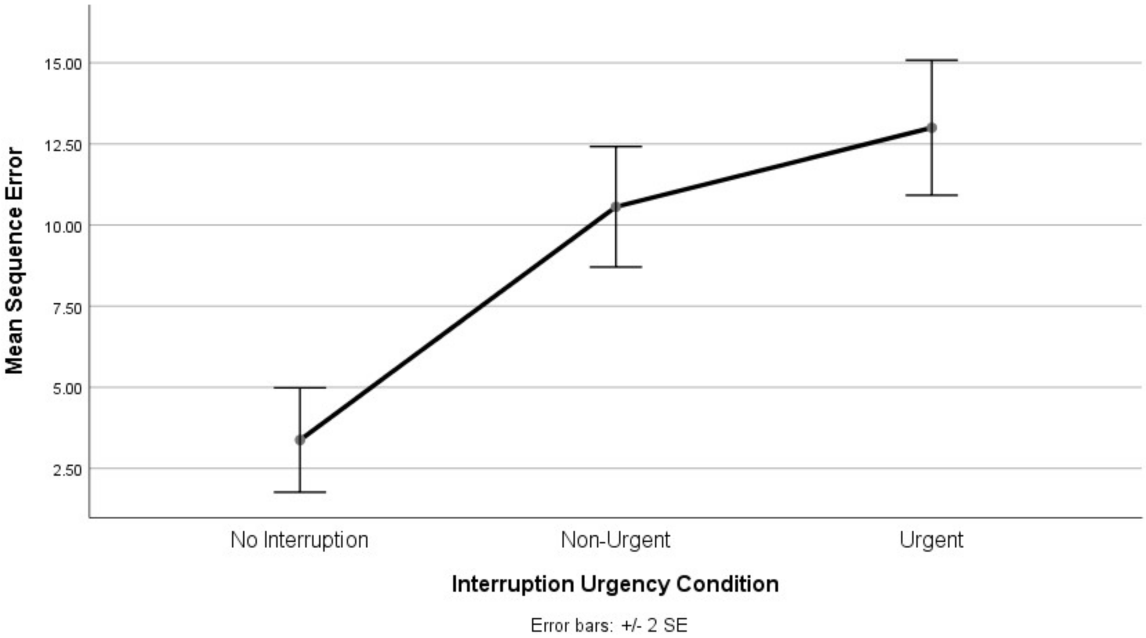


Figure 48 Mean sequence error across interruption urgency conditions.

Interruption Urgency and Emotional Valance Analysis 2 - A comparison of interruption urgency and emotional valance, and the interaction of both through examining post-interruption sequence errors (errors occurring directly after the interruption upon resumption of primary task).

A 2 (Interruption Urgency: Non-Urgent, Urgent) x 3 (Emotional Valance: Neutral Valance, Positive Valance, Negative Valance) repeated measures ANOVA was used to explore whether the number of post-interruption sequence errors significantly increased/decreased directly after resuming a primary task across each urgency and emotional valance manipulation along with the interacting effect of them both. Results indicated a significant main effect of interruption urgency on the number of post-interruption sequence errors being made, $F(1, 31) = 4.27$, MSE = 1.02, $p < .05$, $\eta^2_p = .121$, with more post-interruption sequence errors being made in the Urgent condition ($M = 1.84$, $SD = .785$) compared to the non-Urgent condition ($M = 1.54$, $SD = .810$, $p < .05$).

There was a significant main effect of emotional valance on sequence errors being made $F(2, 62) = 13.22$, MSE = .584, $p < .001$, $\eta^2_p = .299$. Interestingly, Bonferroni post-hoc comparisons indicated significantly more sequence errors were being made in the positive valance condition ($M = 2.09$, $SD = .874$) compared to the Neutral Valance ($M = 1.50$, $SD = .718$, $p < .01$), and Negative Valance ($M = 1.48$, $SD = .837$, $p < .001$) conditions. There was no significant interaction between interruption urgency and emotional valance on the number of sequence errors being made $F(2, 62) = .095$, MSE = .713, $p > .05$, $\eta^2_p = .003$ (Figure 49).

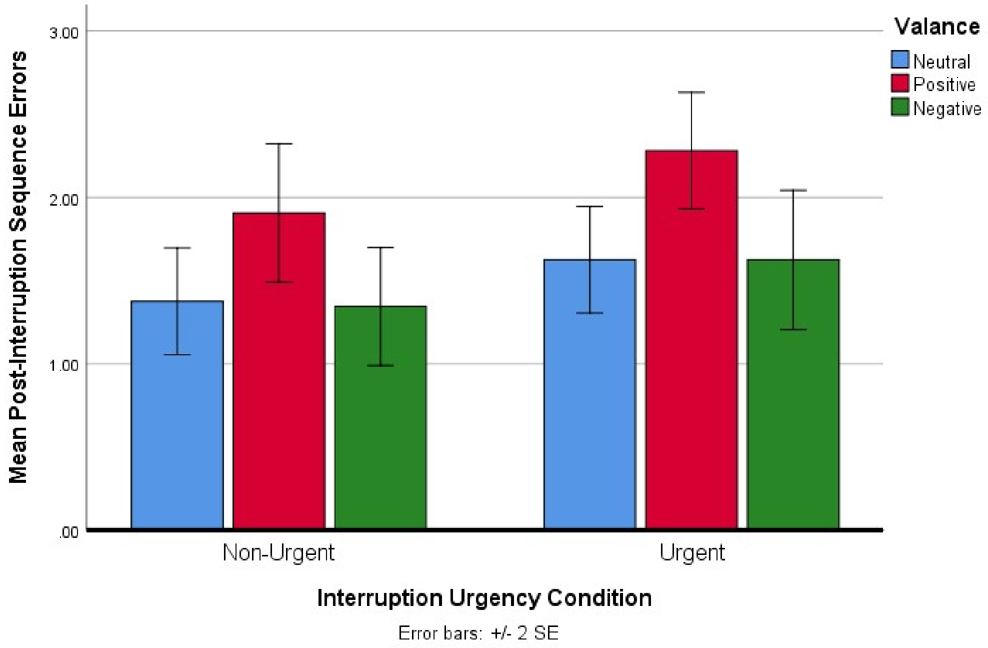


Figure 49 Comparison of sequence error across interruption urgency and emotional valance conditions.

Interruption Urgency and Emotional Valance Analysis 3 - General effect of interruption urgency, CAMROSE task step, and the interaction of both on sequence errors.

A 3 (Interruption Urgency: No Interruption, Non-Urgent Interruption, Urgent Interruptions) x 7 (CAMROSE Task Step: Step 1 (C), Step 2 (A), Step 3 (M), Step 4 (R), Step 5 (O), Step 6 (S), Step 7 (E)) repeated measures ANOVA was used to explore the main effect of interruption urgency and CAMROSE task step as well as the interacting effect on sequence errors (Figure 54). A significant main effect was found for interruption urgency on the number of sequence errors made on a CAMROSE task step *F*(2, 62) = 62.10, MSE = 1.85, $p < .001$, $\eta^2_p = .667$. Bonferroni post-hoc analysis revealed a liner trend in that as interruption urgency increase, so did the number of sequence errors on a CAMROSE task step. Significantly more sequence errors were made in the Urgent condition (*M* = 1.86, *SD* = .843) compared to the No Interruption (*M* = .482, *SD* = .649, $p <.001$) and Non-Urgent (*M* = 1.50, *SD* = .750, $p <.05$). Furthermore, significantly more sequence errors were made in the non-Urgent condition compared to the No Interruption condition ($p <.001$).

There was a significant main effect of CAMROSE task step on the number of sequence errors being made, *F*(2.55, 79.33) = 8.20, MSE = 8.53, $p < .001$, $\eta^2_p = .209$. Bonferroni pairwise comparisons revealed that more sequence errors appeared to occur at CAMROSE task step 2 (A) (*M* = 2.22, *SD* = 1.63) compared to CAMROSE task step 3 (M) (*M* = 1.18, *SD* = .793, $p <.05$) task step 4 (R) (*M* = 1.56, *SD* = 1.44, $p <.05$), task step 5 (O) (*M* = .594, *SD* = .783, $p <.01$), task step 6 (*M* = 1.12, *SD* = 1.02, $p <.001$) and task step 7 (E) (*M* = .729, *SD* = .564, $p <.001$). Furthermore, whilst CAMROSE task step 5 (O) and task step 7 (E) did not significantly differ in terms of sequence errors, both task steps revealed significantly less sequence was made in comparison to all other task steps (*p's* <.05)

There was a significant interaction between interruption urgency and CAMROSE task step on the number of sequence errors being made, *F*(6.01, 186.56) = 3.14, MSE = 2.24, $p < .01$, $\eta^2_p = .092$. Bonferroni post-hoc analysis revealed a trend in that significantly less sequence errors were being made across each CAMROSE task step in the No Interruption compared to the same task step in either the Non-Urgent or Urgent conditions (*p's* <.05). In addition to this finding, significantly more sequence errors were being made on CAMROSE task 6 (S) in the Urgent condition (*M* = 1.90, *SD* = 1.51) compared to sequence errors on the same task position in the non-Urgent condition (*M* = 1.18, *SD* = 1.06, $p <.05$). There were no other significant differences with *p's* >.05.

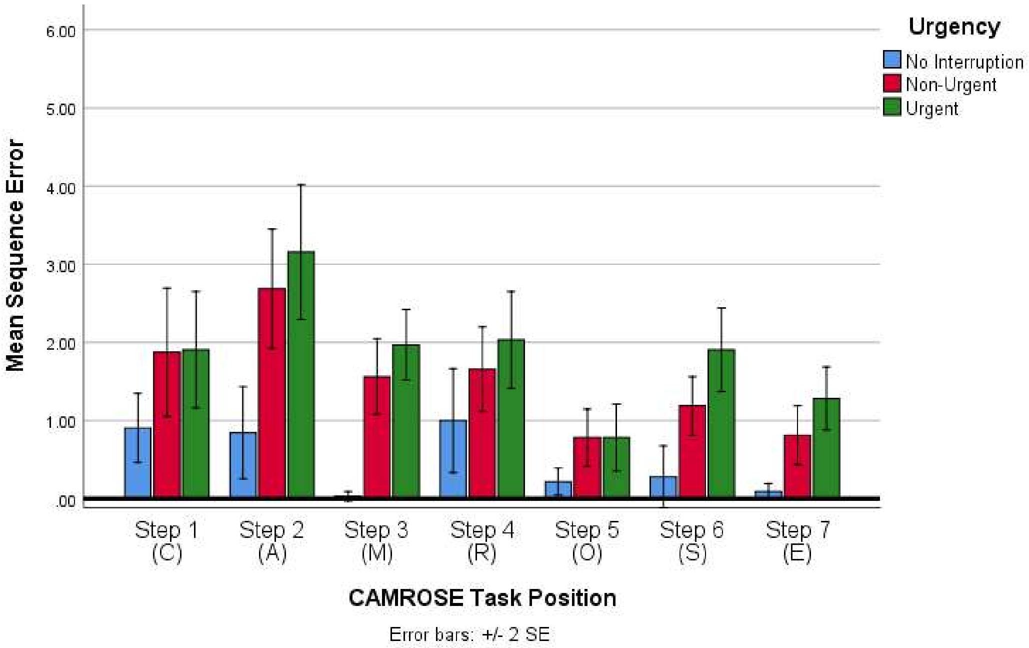


Figure 50 Sequence errors across each CAMROSE task step for each interruption urgency condition.

Interruption Urgency and Emotional Valance Analysis 4 - Comparison of post-interruption sequence errors (errors occurring directly after the interruption upon resumption of primary task) compared to no interruption (control) sequence errors through comparison of interruption urgency, CAMROSE task step, and the interaction of both.

A 3 (Interruption Urgency: No Interruption, Non-Urgent, Urgent) x 7 (CAMROSE Task Step: Step 1 (C), Step 2 (A), Step 3 (M), Step 4 (R), Step 5 (O), Step 6 (S), Step 7 (E)) repeated measures ANOVA was used to explore the main effect of interruption urgency and CAMROSE task step as well as the interacting effect on post-interruption sequence errors (Figure 55). There was no significant main effect of interruption urgency on the number of post-interruption sequence errors being made on a CAMROSE task step, *F*(1.50, 46.50) = 2.48, MSE = 1.28, $p > .05$, $\eta^2_p = .074$. Despite this, there did appear to be a trend emerging in that as the urgency of the interruption increased so did the number of post-interruption sequence errors, both of which were higher than the average sequence error made in the No Interruption condition.

There was a significant main effect of CAMROSE task step on the number of post-interruption sequence errors being made, *F*(2.95, 91.54) = 4.46, MSE = 1.13, $p < .01$, $\eta^2_p = .126$. Bonferroni post-hoc comparisons revealed that significantly more post-interruption sequence errors were being made on CAMROSE task step 4 (R) (*M* = .833, *SD* = .775) compared to CAMROSE task step 2 (A) (*M* = .354, *SD* = .541, p <.001) and task step 3 (M) (*M* = .406, *SD* = .290, p <.05). There were no other significant differences in post-interruption sequence errors across CAMROSE task step with *p's* >.05.

There was a significant interaction between interruption urgency and CAMROSE task position on the number of post-interruption sequence errors being made *F*(3.73, 115.89) = 6.59, MSE = 1.76, $p < .001$, $\eta^2_p = .175$. Bonferroni post-hoc analysis revealed significantly more post-interruption sequence errors were occurring at CAMROSE task step 3 (M) in the Non-Urgent (*M* = .562, *SD* = .564) and Urgent (*M* = .625, *SD* = .491) compared to sequence errors in the No Interruption condition on the same position (*M* = .031, *SD* = .176) conditions with p's <.001. The same significant trend was also found on CAMROSE task step 5 (O) where more post-interruption sequence errors were made in the Non-Urgent (*M* = .812, *SD* = .692) and Urgent (*M* = .812, *SD* = .721) compared to sequence errors in the No Interruption condition on the same task step (*M* = .218, *SD* = .490) with *p's* <.01. Furthermore, this trend continued CAMROSE task step 7 (E) where significantly more post-interruption sequence errors were made in the Non-Urgent (*M* = .656, *SD* = .700) and Urgent (*M* = 1.00, *SD* = .622) conditions compared to sequence errors in the No Interruption condition on the same task position (*M* = .093, *SD* = .296) with *p's* <.01.

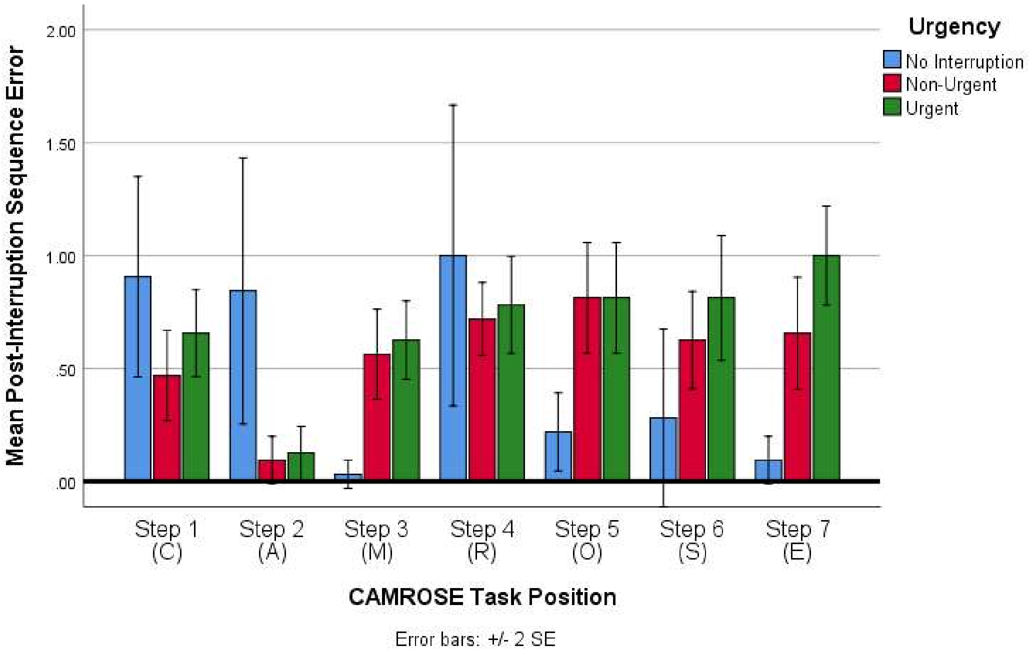


Figure 51 Post interruption sequence errors across each CAMROSE task step for each interruption urgency and emotional valance condition.

Interruption Urgency and Emotional Valance Analysis 5 - General effects of interruption urgency on non-sequence errors during CAMROSE Medication Pre-Administration Task

A repeated measure analysis of variance (ANOVA) was used to evaluate the effects of interruption urgency (No Interruption, Non-Urgent, Urgent) on the number of non-sequence errors made. Results indicated a partially significant effect of interruption urgency on the number of non-sequence errors being made, $F(1.53, 47.65) = 3.80$, MSE = 2.71, $p = .04$, $\eta^2_p = .109$. Despite such finding the Bonferroni post-hoc analyses on revealed a partially non-significant difference between the Non-Urgent ($M = .875$, $SD = 1.12$) and Urgent ($M = 1.84$, $SD = 2.28$) where $p = .074$ (Figure 52).

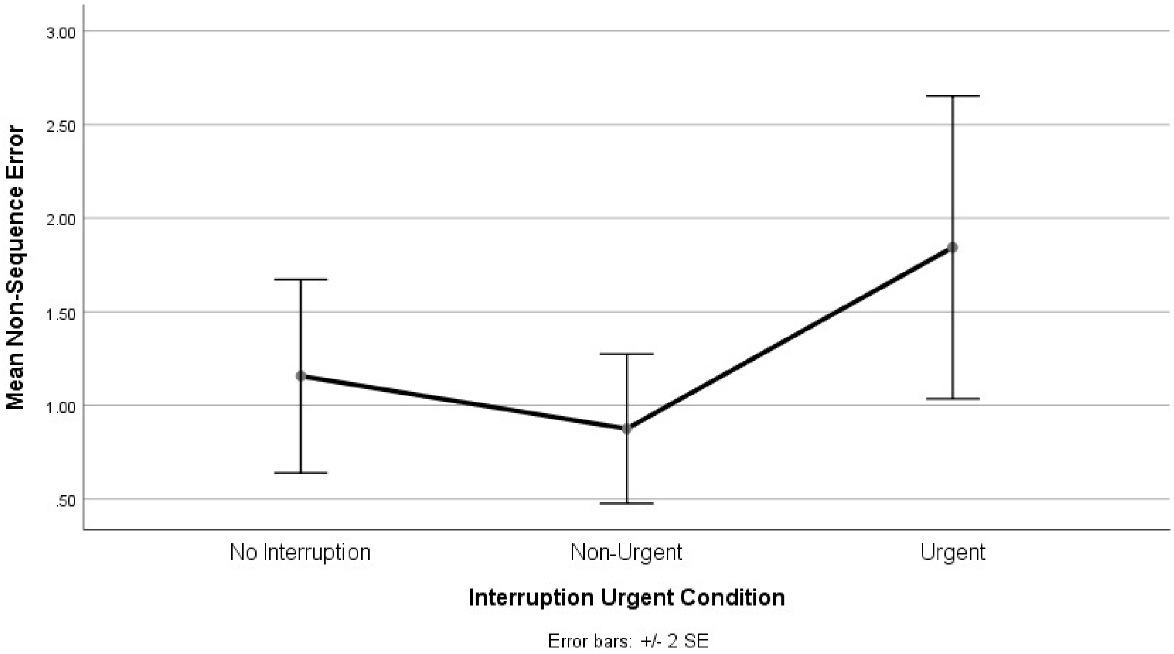


Figure 52 Mean non-sequence errors across interruption urgency conditions.

Interruption Urgency and Emotional Valance Analysis 6 - A comparison of interruption urgency and emotional valance and the interaction of both through examining post-interruption non-sequence errors (errors occurring directly after the interruption upon resumption of primary task).

A 2 (Interruption Urgency: Non-Urgent, Urgent) x 3 (Emotional Valance: Neutral Valance, Positive Valance, Negative Valance) repeated measures ANOVA was used to explore whether the number of post-interruption non-sequence errors significantly increased / decreased directly after resuming a primary task across each urgency and emotional valance manipulation along with the interacting effect of them both. There was a significant main effect of interruption urgency on the number of non-sequence errors being made, $F(1, 31) = 5.90$, MSE = .226, $p < .05$, $\eta^2_p = .160$. Pairwise comparisons revealed that significantly more non-sequence errors were being made in the Urgent (M = .281, SD = .360) condition compared to the Non-Urgent (M = .115, SD = .181) condition with $p < .05$, regardless of the emotional nature of the interruption. There was no significant main effect for emotional valance, $F(2, 62) = .412$, MSE = .164, $p > .05$, $\eta^2_p = .013$ and no significant interaction between interruption urgency and emotional valance, $F(2, 62) = .648$, MSE = .153, $p > .05$, $\eta^2_p = .020$ (Figure 53).

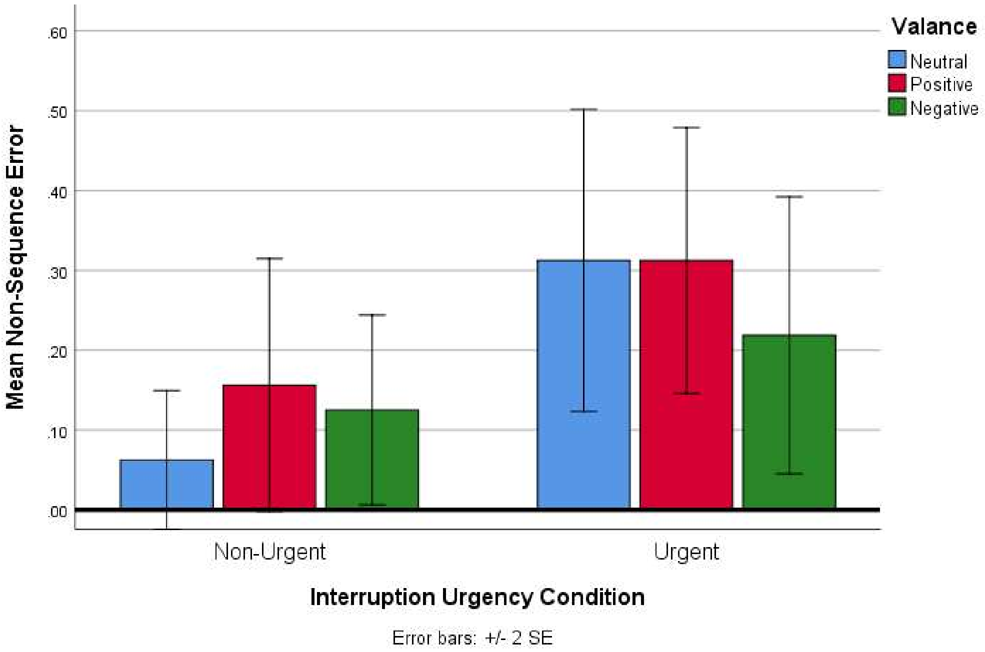


Figure 53 Mean non-sequence errors across interruption urgency and emotional valance conditions.

Interruption Urgency and Emotional Valance Analysis 7 - General effect of interruption urgency, CAMROSE task step, and the interaction of both on non-sequence errors.

A 3 (Interruption Urgency: No Interruption, Non-Urgent, Urgent) x 7 (CAMROSE Task Step: Step 1 (C), Step 2 (A), Step 3 (M), Step 4 (R), Step 5 (O), Step 6 (S), Step 7 (E)) repeated measures ANOVA was used to explore the main effect of interruption urgency and CAMROSE task step as well as the interacting effect on non-sequence errors (Figure 54). There was a partially significant main effect of interruption urgency on the number of non-sequence errors being made on each task step, $F(1.53, 47.65) = 3.80$, MSE = .388, $p = .04$, $\eta^2_p = .109$. Despite a trend in that more non-sequence errors were being made on a CAMROSE task step as urgency was increasing, Bonferroni pairwise comparison revealed no significant differences. There was a partially non-significant main effect of CAMROSE task step on the number of non-sequence errors being made, $F(3.78, 117.22) = 2.44$, MSE = .274, $p = >.05$, $\eta^2_p = .073$.

There was a significant interaction between interruption urgency and CAMROSE task step on the number of non-sequence errors being made, $F(5.51, 170.92) = 2.71$, MSE = .430, $p < .05$, $\eta^2_p = .081$. Bonferroni post-hoc analysis revealed that significantly more non-sequence errors were occurring on CAMROSE task step 3 (M) when occurring in the Urgent condition ($M = .343$, $SD = .601$) compared to non-sequence errors on the same task step in the No Interruption condition ($M = .031$, $SD = .176$, $p < .05$). There were no other significant interactions with all *p's* >.05.

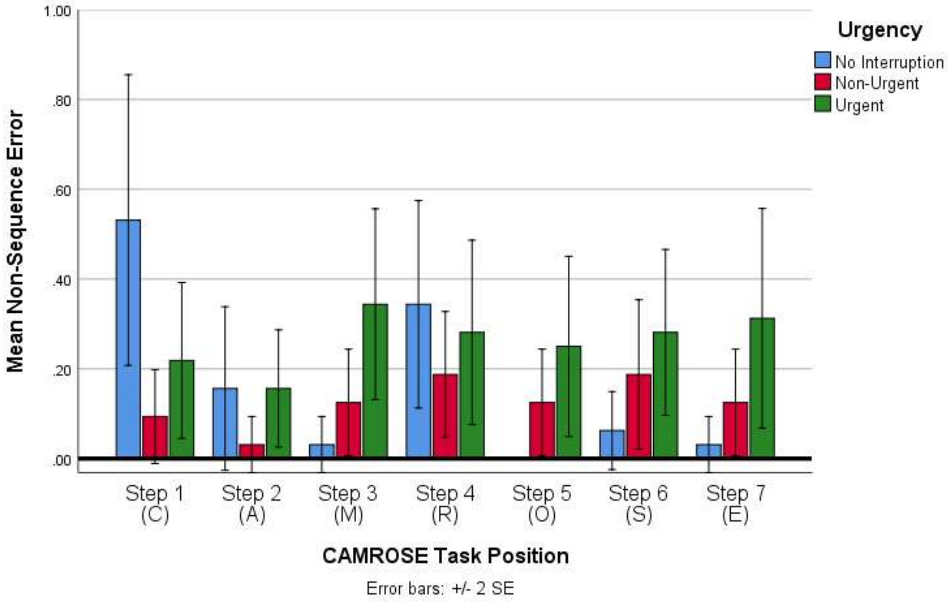


Figure 54 Non sequence errors across each CAMROSE task step for each interruption urgency condition.

Interruption Urgency and Emotional Valance Analysis 8 - Comparison of post-interruption non-sequence errors (errors occurring directly after the interruption upon resumption of primary task) compared to no interruption (control) sequence errors through comparison of interruption urgency, CAMROSE task step, and the interaction of both.

A 3 (Interruption Urgency: No Interruption, Non-Urgent, Urgent) x 7 (CAMROSE Task Step: Step 1 (C), Step 2 (A), Step 3 (M), Step 4 (R), Step 5 (O), Step 6 (S), Step 7 (E)) repeated measures ANOVA was used to explore the main effect of interruption urgency and CAMROSE task step as well as the interacting effect on post-interruption non-sequence errors (Figure 59). A significant main effect was revealed across interruption urgency on the number of post-interruption non-sequence errors made on a CAMROSE task step $F(1.71, 53.27) = 5.89$, MSE = .161, $p < .01$, $\eta^2_p = .160$. Bonferroni pairwise comparisons indicate that significantly more non-sequence errors were being made in the No Interruption condition compared to post-interruption non-sequence errors in the non-Urgent condition ($p < .01$). There was no other significant difference with all *p's* >.05.

There was a significant main effect of CAMROSE task step on the number of post-interruption non-sequence errors being made, $F(3.76, 116.58) = 3.11$, MSE = .578, $p < .05$, $\eta^2_p = .091$. Bonferroni post-hoc analysis did not reveal any significant differences on non-sequence errors across CAMROSE task step.

There was a significant interaction between interruption urgency and CAMROSE task step on the number on post-interruption non-sequence errors being made $F(4.32, 134.11) = 4.51$, MSE = .329, $p < .01$, $\eta^2_p = .127$. It was revealed in the Bonferroni post-hoc analyses that significantly more non-sequence errors were made on CAMROSE task step 1 (C) (*M* = .531, *SD* = .915), and CAMROSE task step 4 (R) (M = .343, SD = .653) in the No Interruption condition compared to post-interruption non-sequence errors in the Non-Urgent condition on the same task step with *p's* <.05. There was no other significant difference with all *p's* >.05.

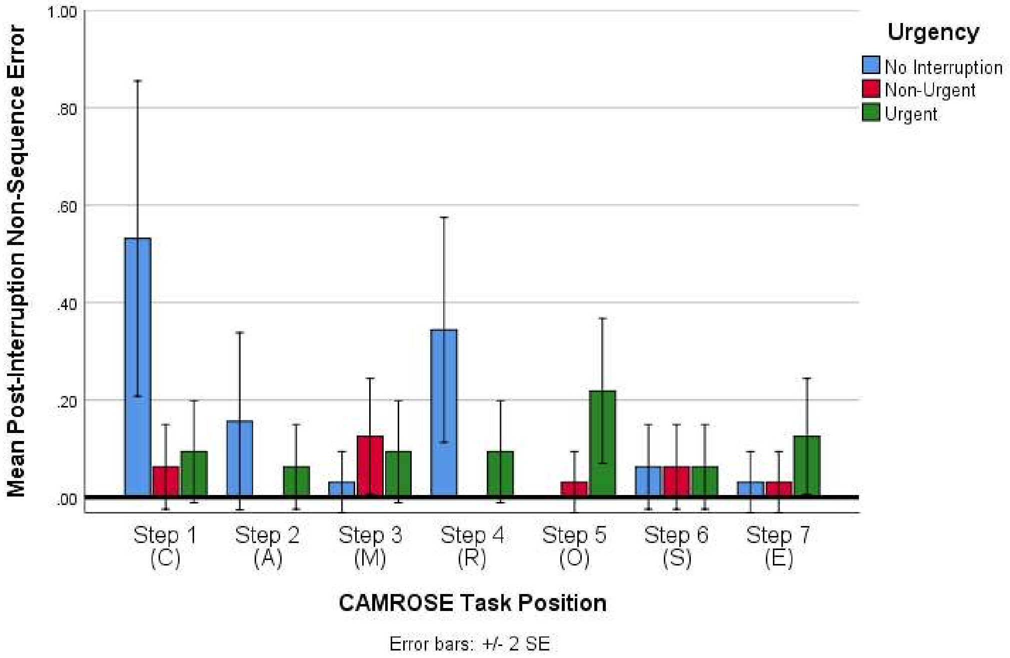


Figure 55 Post interruption non sequence errors across each CAMROSE task step for each interruption urgency and emotional valance condition.

Interruption Urgency and Emotional Valance Analysis 9 - General comparison of inter-action interval (time between to respond to each CAMROSE task step) across each interruption urgency condition.

A repeated measure analysis of variance (ANOVA) was used to evaluate the effects of interruption urgency (No Interruption, Non-Urgent, Urgent) on the average time (seconds) to make a response on a task step (inter-action interval). There was a significant effect of interruption urgency on the inter-action interval, *F*(2, 62) = 5.85, MSE = .902, p <.01, η^2_p = .159. Bonferroni post0hov analysis revealed that participants took significantly longer to make a response in both the Non-Urgent (*M* = 2.74, *SD* = 1.06) and Urgent (*M* = 2.67, *SD* = 1.25) conditions compared to the No Interruption condition (*M* = 2.02, *SD* = .835) with *p's* <.05.

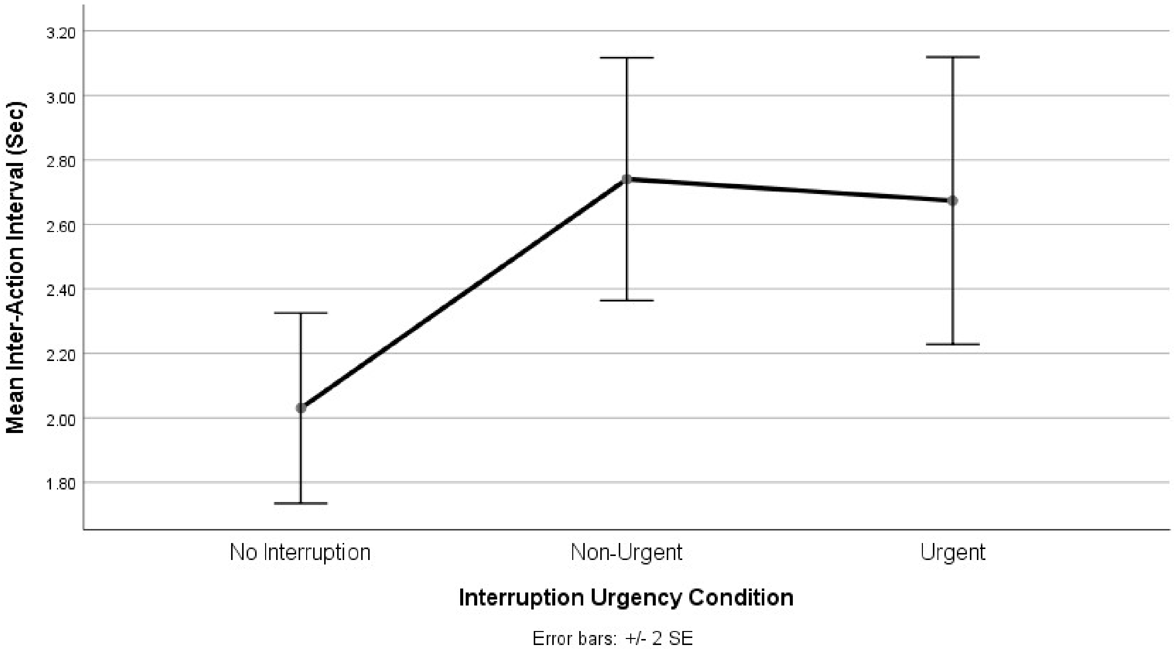


Figure 56 Mean time to perform each step across each experimental condition.

Interruption Urgency and Emotional Valance Analysis 10 - Comparison of post-interruption resumption lag (time between end of interruption and first response back onto primary task) compared to inter-action interval for urgency and emotional valance.

A 2 (Interruption Complexity: Non-Urgent, Urgent) x 3 (Emotional Valance: Neutral, Positive and Negative) within participants ANOVA was used to explore the effects of complexity, emotional valance, and interaction of the two on resumption lag (Figure 57). There was no significant main effect of interruption urgency on resumption lag, $F(1, 31) = 1.00$, MSE = 1.59, p >.05, $\eta^2_p = .031$. There was no significant main effect of emotional valance on the time to resume the primary task, $F(1.46, 45.42) = 3.20$, MSE = .1.51, p > .05, $\eta^2_p = .0.94$. There was no significant interaction between interruption urgency and emotional valance on resumption lag, $F(1.59, 49.39) = .064$, MSE = 2.07, p >.05, $\eta^2_p = .002$.

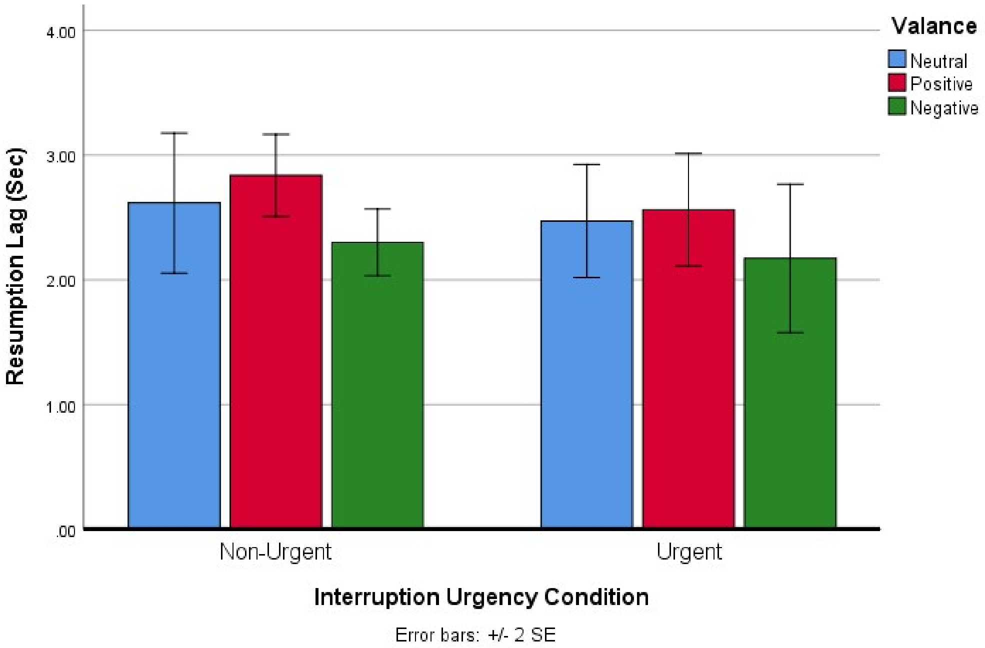


Figure 57 Comparison of resumption lag across interruption urgency and emotional valance conditions.

Paired samples t-tests were used to evaluate for differences between resumption lag and inter-action interval on each urgency and emotional valance manipulation. For the Non-Urgent condition, results indicated that there was no significant difference in the average inter-action interval ($M = 2.74$, $SD = 1.06$) compared to resumption lag for Neutral valanced interruptions ($M = 2.61$, $SD = 1.58$), $t(31) = .898$, p >.05. There was also no significant difference between the resumption lag for Positive valanced interruptions ($M = 2.83$, $SD = .931$) compared to the average inter-action interval $t(31) = .416$, $p > .05$. However, resumption lag for Negative valanced interruptions were significantly lower (*M* = 2.30, *SD* = .757) compared to the average inter-action interval *t*(31) = 2.27, *p* <.05 (Figure 58).

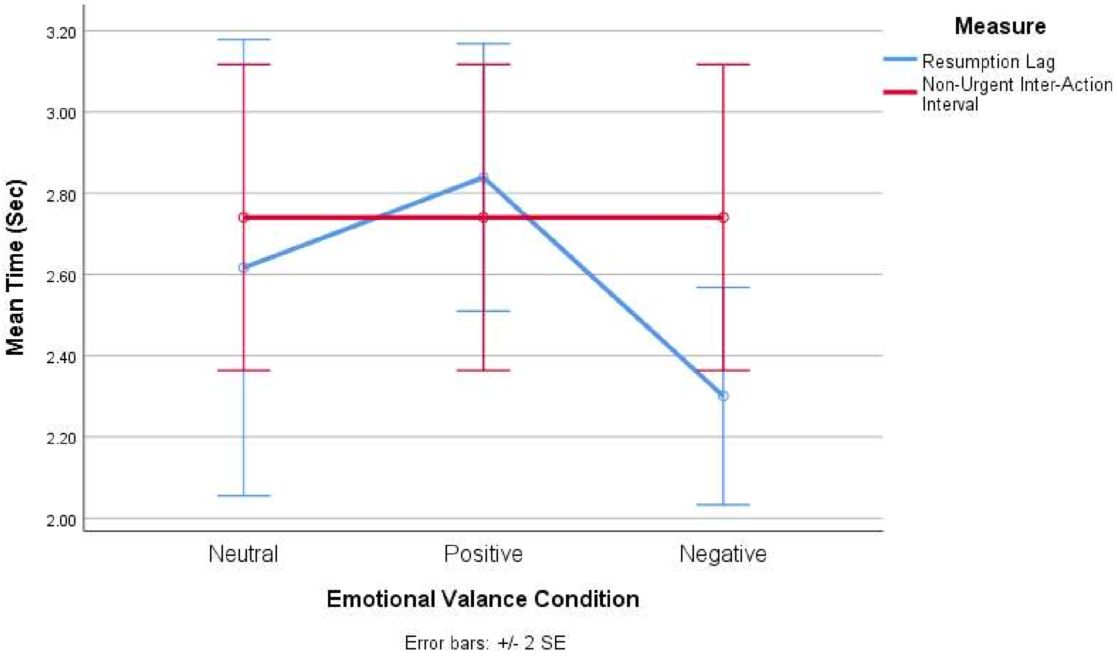


Figure 58 Comparison of resumption lag and inter-action interval in non-urgent interruptions across emotional valance conditions.

In the Urgent condition, there was no significant difference between the average inter-interval (*M* = 2.67, *SD* = 1.25) and resumption lag in the Neutral condition (*M* = 2.47, *SD* = 1.28) *t*(31) = 1.14, *p* >.05. The same was also present in the Positive condition (*M* = 2.55, *SD* = 1.27) *t*(31) = .649, *p* >.05, and the Negative condition (*M* = 2.17, *SD* = 1.68) *t*(36) = 1.80, *p* >.05 (Figure 59).

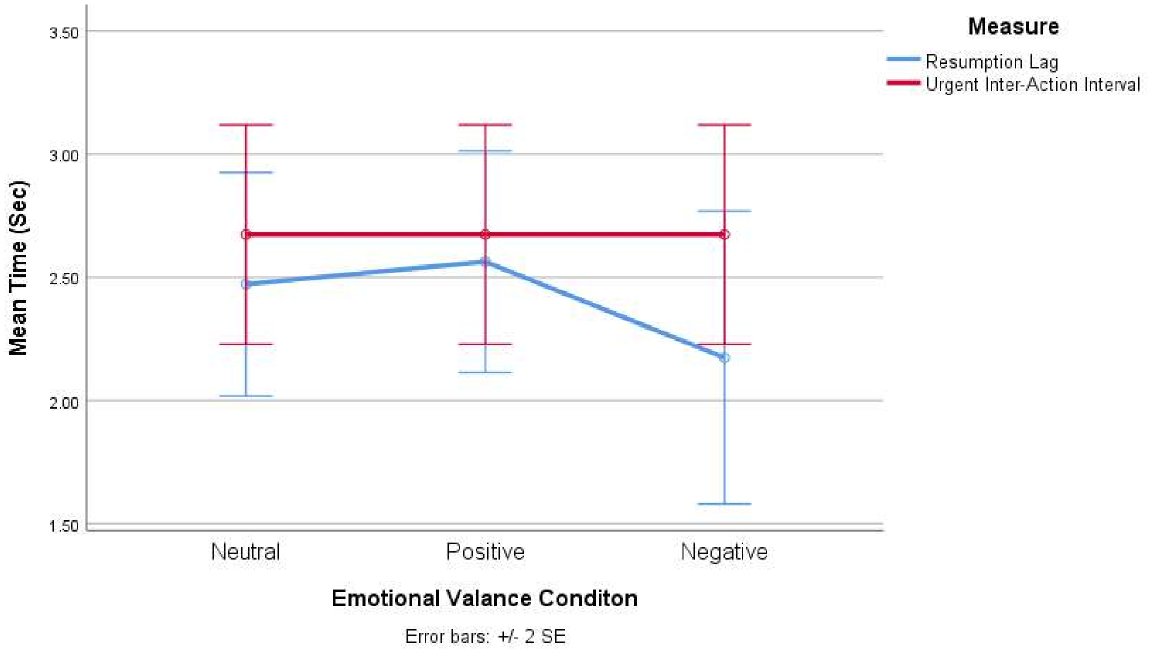


Figure 59 Comparison of resumption lag and inter-action interval in urgent interruptions across emotional valance conditions.

Analysis 11 - Comparison of resumption lag compared to no interruption (control) inter-action interval across interruption urgency, CAMROSE task step, and the interaction of both.

A 3 (Interruption Urgency: No Interruption, Non-Urgent, Urgent) x 7 (CAMROSE Task Step: Step 1 (C), Step 2 (A), Step 3 (M), Step 4 (R), Step 5 (O), Step 6 (S), Step 7 (E)) repeated measures ANOVA was used to explore the main effect of interruption urgency and CAMROSE task step as well as the interacting effect on resumption lag (Figure 60). A significant main effect was found on interruption urgency on time to complete a CAMROSE task step $F(1.39, 43.24) = 43.13$, MSE = 19.62, $p < .001$, $\eta^2_p = .582$. Bonferroni pairwise comparisons indicated that it took significantly longer to resume a task step after an interruption in the Non-Urgent ($M = 4.88$, $SD = 1.19$), and Urgent ($M = 4.59$, $SD = 2.12$) conditions compared to the average time to complete the same task step in the No Interruption condition ($M = 1.93$, $SD = .850$) with all *p's* <.001.

There was a partial significant main effect of CAMROSE task step on the time to complete a task step $F(3.61, 112.02) = 2.61$, MSE = 13.41, $p = .044$, $\eta^2_p = .078$. Bonferroni post-hoc analysis revealed that significantly less time was needed to respond to CAMROSE task step 2 (A) ($M = 2.90$, $SD = 1.09$) compared to CAMROSE task step 1 (C) ($M = 4.37$, $SD = 1.76$, $p < .001$), CAMROSE task step 4 (R) ($M = 3.85$, $SD = 1.56$, $p < .05$) and CAMROSE task step 7 (E) ($M = 4.19$, $SD = 1.81$, $p < .01$).

There was a significant interaction between interruption urgency and CAMROSE task step on resumption time $F(4.43, 137.40) = 2.99$, MSE = 19.54, $p < .05$, $\eta^2_p = .088$. Bonferroni post-hoc analysis revealed that it took significantly longer to resume the primary task in the non-Urgent condition on CAMROSE task step 1 (C) ($M = 5.44$, $SD = 2.62$) compared to the average time to make a response on the same task step in the No Interruption condition ($M = 3.18$, $SD = 2.12$, $p < .001$). Furthermore, it took significantly longer to resume the primary task in the non-Urgent condition on CAMROSE task step 3 (M) compared to resumption in the Urgent condition on the same task step ($M = 3.67$, $SD = 2.01$), whilst both were significantly longer than the average time to make a response in the No Interruption condition on the same task step ($M = 1.60$, $SD = 1.06$) with all *p's* <.001. This pattern continued in that resumption was longer in both the Non-Urgent and Urgent conditions on task steps compared to the average time on the same task step in the no Interruption condition with all *p's* <.01.

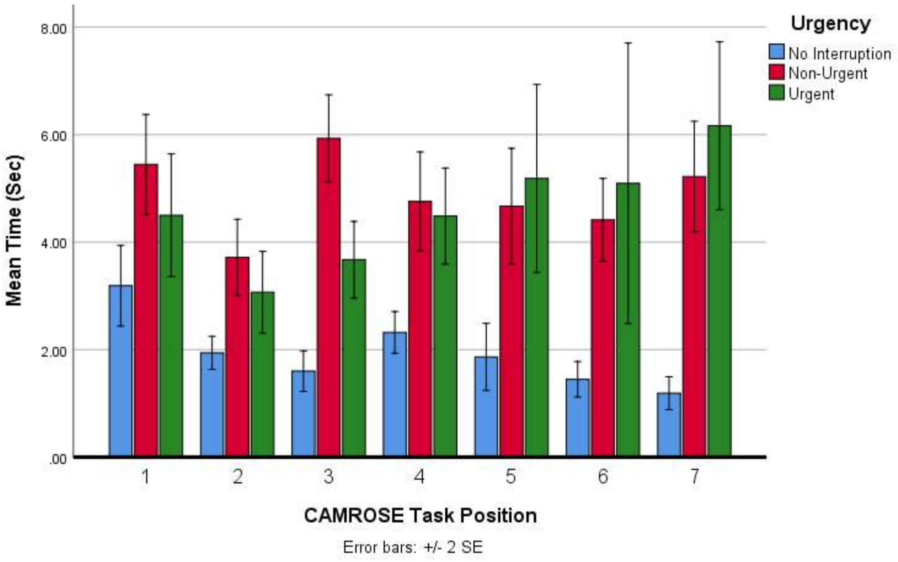


Figure 60 Comparison of resumption lag and inter-action interval across each CAMROSE task step for urgent interruption conditions.

Summary

There were significantly more sequence errors being made on interruption conditions compared to the no interruption condition. Less sequence errors were made in the no interruption condition compared to both urgent and non-urgent interruptions. Furthermore, participants on average made significantly more errors when interruptions were urgent compared to non-urgent. These effects were also present for post interruption sequence errors where on average more post interruption sequence errors were made when interruptions were urgent compared to non-urgent. There was a partially significant effect of interruption urgency on non-sequence errors although post hoc analysis did not indicate any significant differences.

In relation to predictions made for the effects of emotional valance on post interruption sequence errors, emotional valance had a significant effect on post interruption sequence errors. Interestingly, participants made significantly more post interruption sequence errors when the interruption was positive valanced compared to negative or neutral partially supporting hypothesis two. This is consistent with the findings reported in experiment 4. There was no significant interaction between interruption urgency and emotional valance on post interruption sequence errors meaning hypothesis three was partially supported. There was a significant effect of interruption urgency on non-sequence post interruption errors where more non-sequence errors were made in urgent conditions compared to non-urgent conditions. There was no significant effect of emotional valance or interaction of interruption urgency and emotional valance on post interruption non-sequence errors.

The inter-action interval for urgency interruptions significantly differed compared to the no interruption condition with both urgent and non-urgent on average taking longer to respond compared to no interruptions. There was no significant difference in the average time to resume the primary task and inter-action interval between urgency conditions. However, participants were significant quicker to make a response after an interruption compared to the inter-action interval in non-urgent conditions when the interruption was negatively valanced. Emotional valance had no significant effect in the urgent condition on the time to resume the primary task compared to the inter-action interval. Collectively, these results differ somewhat from those previously published. For instance, Morgan et al. (2018) observed that both negatively and positively valanced pictures resulted in a decrease in memory recall after a task interruption. However, in experiments 4 and 5, only interruptions with a positive valence affected performance. One possible reason might be linked to the perceived difficulty of the task in these trials, in conjunction with the fact that positive stimuli capture attention more effectively under high task load (Gupta, Hur & Lavie, 2016). This logic suggests that positive disruptions attract attention more than negative interruptions, making it difficult to recall suspended task goals.

The experiments conducted so far in the thesis have aimed to better understand the characteristics of task interruptions that are often stated and the qualities that may be specific to a healthcare setting through the deployment of a novel contextually relevant experimental task. There has been a general pattern observable throughout, in that when considering both primary and interruption task constraints through mimicking healthcare tasks, interruption effects, whilst still present, differ in terms over effect. An overarching trend has emerged, demonstrating that interruption effects, while still present, vary in terms of severity when primary and interruption task constraints are included to mimic healthcare-related activities. This is evident in both general interruption characteristics and healthcare specific characteristics. Although there are caveats to be taken into account when interpreting such results (discussed in Chapter 7), these findings offer a fresh perspective on the problem of healthcare interruptions and the various consequences these features can have. When taking into account the context of its application, the consistency of findings (such as complexity and emotional valence) shows a step towards better understanding the application of theoretical explanations. This will not only improve our existing understanding, but also pave the way for exploring potential solutions to the problems caused by interruptions in healthcare. To this end, the next intervention experiment takes this direction by employing the experimental task to inquire into the efficacy of an interface intervention.

Chapter 6: Exploring the utility of a novel intervention to minimise the disruptive effects of task interruptions.

Experiment 6: Manipulating information access cost to induce behaviour change in handling task interruptions.

Experimental Hypotheses

Behavioural strategies for dealing with the disruptive effects of interruptions typically don't focus on isolating tasks or eliminating interruptions entirely. Therefore, understanding effective behavioural strategies may be more applicable in a healthcare setting since not all interruptions are necessarily bad. As there is a growing interest in using technology to assist healthcare professionals, there may be openings in the design of such tools to subtly promote effective cognitive and behavioural strategies that would facilitate the successful handling of task interruptions. The Theory of Soft Constraints (ToSC) proposes that low-level task strategies comprised of perceptual, cognitive, and motor elements are chosen to minimise time costs, with a particular emphasis on interactive behaviour. It was proposed that tasks are made up of hard constraints (which are fixed and determine what interactive behaviour is or is not possible) and soft constraints (which are determined by strategy selection). Although people can't alter the hard requirements of a task, they can influence the soft constraints by deciding on the nature of the strategy they'll use to complete it (Gray & Fu, 2004; Gray, Sims, Fu & Schoelles, 2006).

Cognitive strategy, as described by ToSC, is malleable and can realistically adjust to micro-level changes in the task environment, such as how information is accessed (Gray & Boehm-Davies, 2000). To lessen the load on their own working memory, people will adopt a strategy that treats the task environment as an external memory resource if it provides ready access to the data they need. People will adopt a more internalised strategy, such as encoding the information in memory, if doing so reduces the frequency with which they must access the information and thus the time cost associated with doing so (Gray et al., 2006). To what extent a memory-based strategy is chosen can thus be influenced by manipulating the cost of accessing information.

How simple it is to get your hands on the data you need to get a job done is one definition of "accessibility." The participant's response to this can be influenced by making the information immediately accessible (by placing it on a computer screen next to the task) or by delaying the participant's access to the information (e.g., having to move the mouse cursor to access it). Time, energy, and mental exertion are all components of the "information access cost" (IAC) (Morgan, Patrick and Tiley, 2013). When people have to work harder to access information, they often resort to planning solely from memory (Gray & Fu, 2004; Gray et al., 2006). Results show that this enhances both memory recall and problem-solving ability (Morgan et al., 2009; Waldron, Patrick, & Duggan, 2011; Morgan & Patrick, 2013). It is therefore predicted that in contrast to low and medium information access costs, high information access cost will be more error-proof, but participants will take more time to resume the task after an interruption (*H1*). In addition, it is posited that there will be a noteworthy interaction between interruption complexity and information access cost on performance measures, with high information access cost reducing errors more in higher complexity conditions. Furthermore, in the high information access conditions, post interruption errors will be lower, but in the more complex conditions, they will be higher (*H2*).

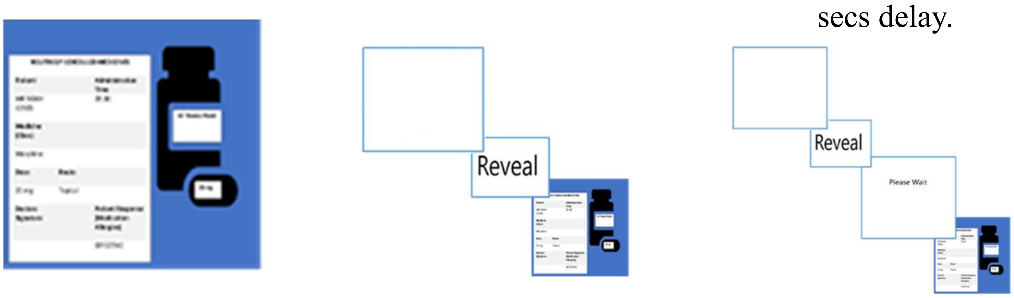
Method

Participants

An opportunity sampling method was used to recruit 76 students aged 18–30 years (M = 19.77; SD = 1.94). 65 participants were female, and 11 were male. Participants were given course credits for their participation linked to their UG BSc Psychology degree research methods training. All participants had normal-corrected vision and hearing and were English first language or highly proficient in English as a second language.

Design

A 3 x 4 mixed (between-within) participant design was utilised to explore the effects and interaction of information access cost and interruption complexity. The between-participant independent variable was information access cost (IAC) with 3 levels (Low IAC (N = 28), Medium IAC (N = 23), High IAC (N = 25)). IAC was determined by the time cost associated with accessing the CAMROSE information post-interruption (Low = Task information always available, Medium = Mask covering task information which is removed when the mask is clicked with the mouse, High = The same as medium but with an additional time cost of 2 seconds before the mask is removed, Figure 61). The within-subjects variable was interruption complexity, defined like the previous experiments; the extent of cognitive load the task created and determined by the number of steps required to complete the interruption task: one for Low Complexity, three for Moderate Complexity, and five for High Complexity.


Low IAC

Information always available

Moderate IAC

Click reveal for information.

High IAC

Click reveal for information, but with 2.5 secs delay.

Figure 61 Example of information access cost conditions.

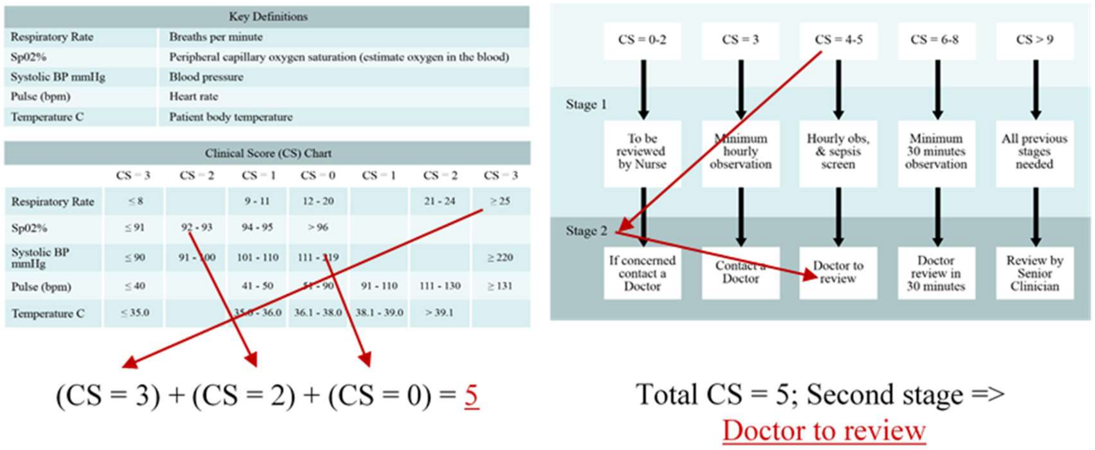
Given the nature of the CAMROSE procedural primary task, a number of dependent variables (DV) were recorded. DV-1 was sequence errors which was determined by the incorrect step performed (e.g., a step that does not logically follow on from the previous step). DV-2 was non-sequence errors when the correct step is performed but with the wrong response (each step has two possible responses). Both DV's will provide insights into task accuracy both overall and post-interruption (e.g., errors that occur directly after an interruption upon resumption of the primary task). The post-interruption analysis will also allow for the comparison valance, as valance was balanced within each condition, which is each condition represented a complexity condition with task interruptions varying in valance within them. Timing measures (such as time to resume to primary task – resumption lag) were also recorded to measure task and resumption efficiency. DV-3 was a measure of inter-action interval (resumption lag) by recording the time taken from the end of the interruption until the first keyboard response back on the primary task (Cades et al, 2008). This will allow for the assessment in differences in disruptiveness between interruption task complexity. DV-4 was the reaction time on each step of the primary and interruption task.

Additionally, assessment of initial interaction with the interface would provide additional insight into the potential memory strategies participants may use in the moderate and high information access cost conditions. To this extent, DV-5 was the time spent viewing the experimental stimuli on participants first interaction; DV-6 was the number of errors made after the first interaction and DV-7 was the average number of times participants revealed the experimental stimuli.

Materials

The primary and interruption task used in this experiment is the CAMROSE Medication Pre-Administration Task and Clinical Decision-Making Task. The interface in the no IAC condition was the same in previous experiments. The interface layout for the IAC trials were slightly different from the previous experiments. Upon starting the experiment, participants were present with a masked CAMROSE in the centre of the screen, and a reveal button to the bottom left of the screen. When the reveal button was clicked, the CAMROSE information was displayed either immediately or after a 2 second delay depending on the IAC condition. This would remain present until the participant provided a response, at which point the mask would reappear. At the end of the sequence the medication administration information will change, and participants will be notified with the following notification 'New Patient' when this happens. When the information changes participants were instructed to start the sequence again.

Interruptions were initiated by an image of a nurse confederate along with an audio that would provide them a clinical IF-THEN scenario that required a decision to be made based upon the information ask by the nurse confederate (Figure 62). Such scenarios required participants to work out a clinical physiological score using the paper score chart provided and enter the correct clinical score along with the clinical action required. For example, a moderate complexity interruption could be, "***Patient has a respiratory rate of 28, an Sp02% of 92 and a systolic of 207, what is the second stage required?***" Participants would then add the clinical score and provide the appropriate response relating to that score.



Key Definitions	
Respiratory Rate	Breaths per minute
Sp02%	Peripheral capillary oxygen saturation (estimate oxygen in the blood)
Systolic BP mmHg	Blood pressure
Pulse (bpm)	Heart rate
Temperature C	Patient body temperature

Clinical Score (CS) Chart

	CS = 3	CS = 2	CS = 1	CS = 0	CS = 1	CS = 2	CS = 3
Respiratory Rate	≤ 8		9 - 11	12 - 20		21 - 24	≥ 25
Sp02%	≤ 91	92 - 93	94 - 95	> 96			
Systolic BP mmHg	≤ 90	91 - 100	101 - 110	111 - 119			≥ 220
Pulse (bpm)	≤ 40		41 - 50	51 - 90	91 - 110	111 - 130	≥ 131
Temperature C	≤ 35.0		35.0 - 36.0	36.1 - 38.0	38.1 - 39.0	> 39.1	

(CS = 3) + (CS = 2) + (CS = 0) = 5

Total CS = 5; Second stage => Doctor to review

Figure 62 Example of interruption participants may experience based on a moderate complexity interruption.

To respond accordingly to the interruptions, participants had a paper reference version of the clinical score chart and actions required present at their workstation. Experiments were running within psychology laps on individual workstations (each separated by a partition) that held between 4-16 participants. Each workstation had a desktop PC, computer mouse and keyboard, and over-ear headphones. Interruptions were initiated by an image of a nurse and audio recording of a clinical If-Then scenario. Participants were required to wear headphones provided to stop interference from external noise.

Procedure

Upon entering the experiment room participants were asked to take their time to go through the participant information sheet, and if they were happy to continue sign the consent form. Participants were encouraged to ask questions. Once consent form was signed, they were collected by the researcher and participants asked to put pens away, and ensure their phone is either silent/off and placed in their pocket/bag.

The researcher proceeded to go through the task instructions with the participants and instructed not to continue until told to do so. Once again, participants were strongly encouraged to ask questions at any point if they were unsure about any of the instructions. First, participants were walked through the nature of the CAMROSE step by, and the responses required for each step. It was explained that the task information will need to be revealed at the start of the experiment and at the beginning every time there they were presented with ‘***NEW PATIENT’***, as the stimuli presented on the interface changes. Participants were advised that there would be no visual feedback when entering a response on the keyboard, but the response was being recorded and experimental trials will continue after each response even with the mask present.

At this stage, participants were asked if they had any questions relating to the CAMROSE task before continuing onto practice trials. These practice trials entailed the completion of 14 trials with no task interruptions. Throughout the practice trials the CAMROSE acronym and responses were presented on the screen to help participants familiarise themselves with the acronym and associated responses. Participants were made aware that this was only available for the practise trials and would not be for the main experimental trials, so to ensure they try and remember the acronym and associated responses. Participants were then taken through the task interruption and advised that no one task takes priority, and both are important in the experiment. Participants were instructed that following an interruption and upon returning to the primary task, they are to continue the task from where they left. The mask will be over the stimuli upon resumption. They then completed an additional 14 practice trials with interruptions occurring at various points, and the CAMROSE acronym still present.

After finishing all practice trials participants were asked again if they had any questions relating to what was expected from them in the experiment. Before starting, they were asked to be accurate on both the CAMROSE task and interruption task whilst maintaining the correct sequence. Upon completion of the experiment, a full debrief was given to all participants. The experiment took approx. 90 minutes to complete.

Results

IAC and Interruption Complexity Analysis 1 - General effects and interaction of interruption complexity and information access cost on sequence errors during the CAMROSE Medication Pre-Administration Task.

A mixed between and repeated analysis of variance (ANOVA) was used to evaluate the effects of information access cost (IAC: Low IAC, Moderate IAC, and High IAC) and interruption complexity (Low Complexity, Moderate Complexity, High Complexity) on the number of sequence errors made in the CAMROSE Medication Pre-Administration Task. Results indicated a significant main effect of interruption complexity on the number of sequence errors being made, $F(2.44, 178.5) = 45.90$, MSE = 14.63, $p < .001$, $\eta^2_p = .386$ (Figure 63), with participants making significantly more sequence errors in the Low (*M = 8.9, SE = .74*), Moderate (*M = 8.9, SE = .68*) and High (*M = 9.5, SE = .66*) complexity conditions compared to the No Interruption condition (*M = 3.78, SE = 49*).

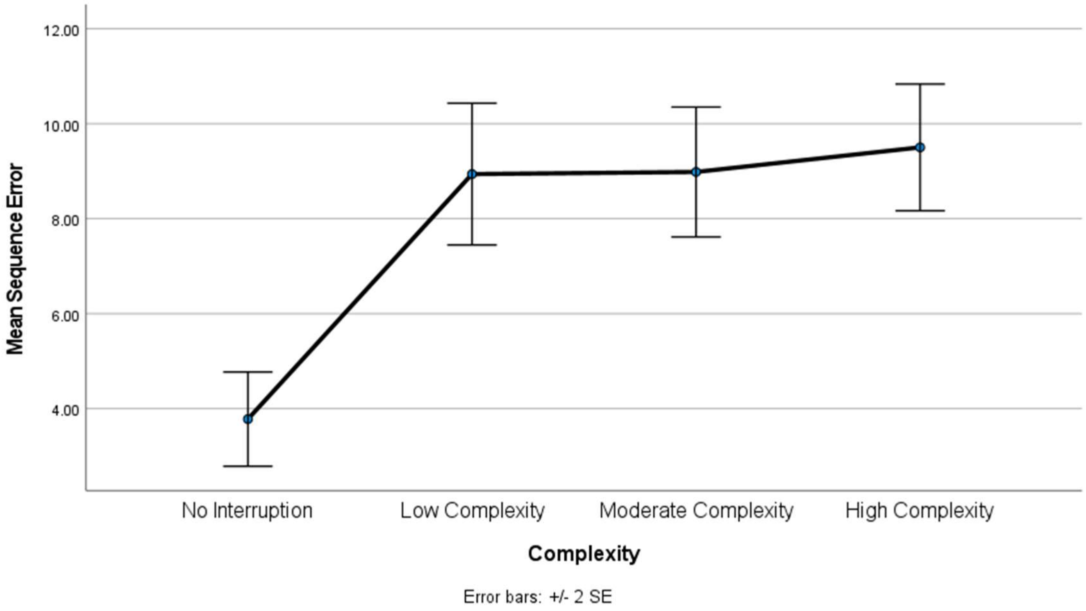


Figure 63 Mean sequence error across interruption complexity conditions in experiment 6.

There was also a significant main effect of information access cost on the number of sequence errors being made $F(2,73) = 5.148$, MSE = 23.42, $p < .01$, $\eta^2_p = .124$ (Figure 67). On average, participants in the Low IAC group made significantly more sequence errors (*M = 9.9, SE = .91*) compared to the High IAC condition *(M = 5.7, SE = 1)*. Despite a trend in that sequence errors were reduced as information access cost increased, there has no significant difference between the Moderate IAC and High IAC.

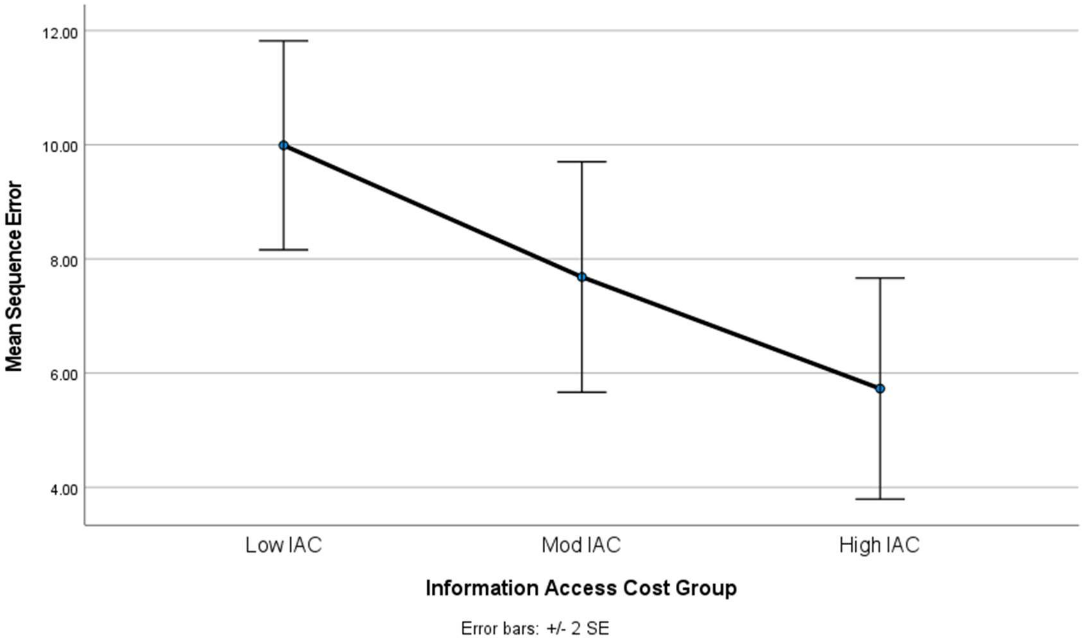


Figure 64 Mean sequence error across information access cost conditions.

There was a significant interaction between interruption complexity and information access cost on the average number of sequence errors being made $F(4.89,178.57) = 3.30$, MSE = 14.63, $p < .01$, $\eta^2_p = .083$ (Figure 68). There were significantly more sequence errors made ($p < .05$) when task interruptions were low in complexity and occurred in the low information access cost group ($M = 11.5$, $SE = 1.22$) compared to the same interruption complexity in the high information access cost condition ($M = 6.32$, $SE = 1.29$). Similar findings were also found where more sequence errors were found in the low information access cost (**Mod**: $M = 11.92$, $SE = 1.23$; **High**: $M = 12.53$, $SE = 1.09$) compared to the high information access cost conditions (**Mod**: $M = 6.20$, $SE = 1.18$; **High**: $M = 7.32$, $SE = 1.15$) with both moderate and high complexity interruptions respectively (all *p's* <.01).

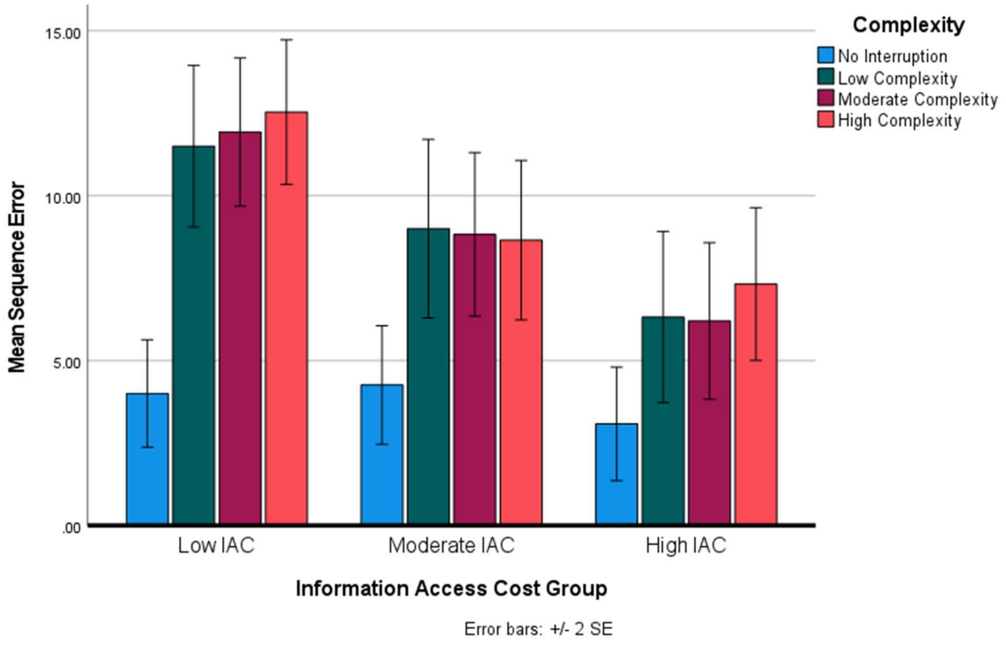


Figure 65. Mean sequence error across interactions between interruption complexity information access cost.

IAC and Interruption Complexity Analysis 2 - A comparison of information access cost in post-interruption sequence errors during the CAMROSE Medication Pre-Administration Task.

A mixed between and repeated analysis of variance (ANOVA) was used to evaluate the effects of information access cost (IAC: Low IAC, Moderate IAC, and High IAC) and interruption complexity (No Interruption, Low Complexity, Moderate Complexity, High Complexity) on the number of post-interruption sequence errors made in the CAMROSE Medication Pre-Administration Task. Despite a trend within the data (Figure 66) in that as interruption complexity increased so did the post-interruption sequence errors, and, as information access cost increased post-interruption sequence error decreased, there were no significant main effect of interruption complexity ($F(1.79,127.71) = .646$, MSE = 2.86, $p > .05$, $\eta^2_p = .009$), information access cost $F(2, 73) = 2.90$, MSE = 16.19, $p > .05$, $\eta^2_p = .074$) or interaction $F(3.49, 127.71) = 567$, MSE = 4.43, $p > .05$, $\eta^2_p = .015$).

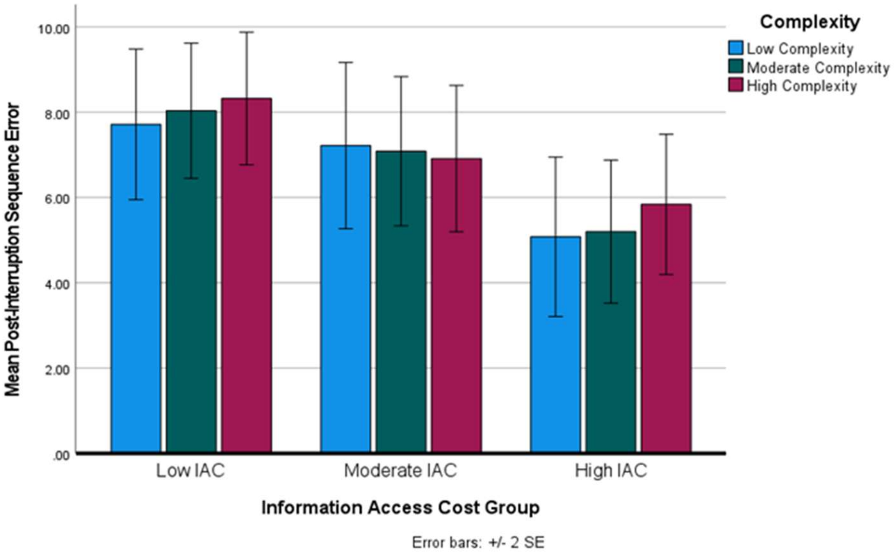


Figure 66 Comparison of post interruption sequence errors across interruption complexity and information access cost.

IAC and Interruption Complexity Analysis 3 - Effect of interruption complexity and information access cost on non-sequence errors during the CAMROSE Medication Pre-Administration Task.

A mixed between and repeated analysis of variance (ANOVA) was used to evaluate the effects of information access cost (IAC: Low IAC, Moderate IAC, and High IAC) and interruption complexity (No Interruption, Low Complexity, Moderate Complexity, High Complexity) on the number of non-sequence errors made in the CAMROSE Medication Pre-Administration Task.

There was no significant main effect of interruption complexity on the number of non-sequence errors made $F(3, 219) = 1.35$, MSE = 1.75, $p > .05$, $\eta^2_p = .018$. There was no significant difference in the number of non-sequence errors being made across information access groups $F(2, 73) = .139$, MSE = 1.76, $p > .05$, $\eta^2_p = .004$, and no significant interaction $F(6, 219) = 2.11$, MSE = 1.75, $p > .05$, $\eta^2_p = .055$.

IAC and Interruption Complexity Analysis 4 - Effect of interruption complexity and information access cost on post-interruption non-sequence errors during the CAMROSE Medication Pre-Administration Task.

A mixed between and repeated analysis of variance (ANOVA) was used to evaluate the effects of information access cost (IAC: Low IAC, Moderate IAC, and High IAC) and interruption complexity (Low Complexity, Moderate Complexity, High Complexity) on the number of post interruption non-sequence errors made in the CAMROSE Medication Pre-Administration Task.

There was no significant main effect of interruption complexity on the number of non-sequence errors made $F(2, 146) = 1.54$, MSE = .293, $p > .05$, $\eta^2_p = .021$. There was no significant difference in the number of non-sequence errors being made across information access groups $F(2, 73) = 2.18$, MSE = .338, $p > .05$, $\eta^2_p = .056$, and no significant interaction $F(4, 146) = 1.43$, MSE = 1.76, $p > .05$, $\eta^2_p = .038$.

IAC and Interruption Complexity Analysis 5 - Comparison of inter-action interval (time to respond to each CAMROSE task step) between interruption complexity and information access cost.

A mixed between and repeated analysis of variance (ANOVA) was used to evaluate the effects of information access cost (IAC: Low IAC, Moderate IAC, and High IAC) and interruption complexity (No Interruption, Low Complexity, Moderate Complexity, High Complexity) on the average inter-action interval in the CAMROSE Medication Pre-Administration Task.

There was significant main effect of interruption complexity on the inter-action interval $F(2.39, 174.52) = 6.64$, MSE = 1.29, $p < .001$, $\eta^2_p = .083$ (Figure 67). On average, participants were significantly longer to make response in the low ($M = 3.78$, $SE = .155$), moderate ($M = 3.67$, $SE = .123$) and high ($M = 3.81$, $SE = .173$) complexity conditions compared to the inter-action interval in the no interruption conditions ($M = 3.16$, $SE = .138$) with all *p's* <.01.

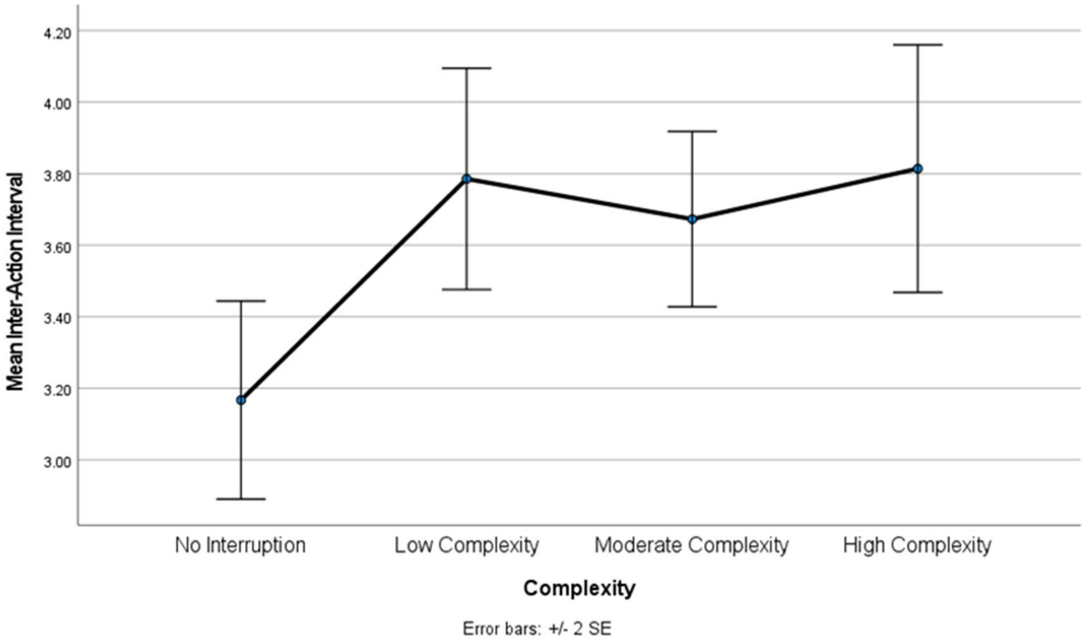


Figure 67 Inter-action interval across interruption complexity condition in experiment 6.

There was a significant main effect of information access cost on the inter-action interval $F(2, 73) = 81.25$, MSE = .888, $p < .001$, $\eta^2_p = .690$ (Figure 68). Participants on average took significantly longer to make a response when information access cost was high ($M = 5.32$, $SE = .188$) compared to the low ($M = 2.01$, $SE = .178$) and moderate ($M = 3.48$, $SE = .196$) conditions with all *p's* <.001. Furthermore, it was on average significantly longer to make a response in the moderate information access cost compared to the low information access cost (*p* <.001). There was no significant interaction between interruption complexity and information access cost on the inter-action interval $F(4.78,174.52) = 6.64$, MSE = 1.29, $p > .05$, $\eta^2_p = .041$.

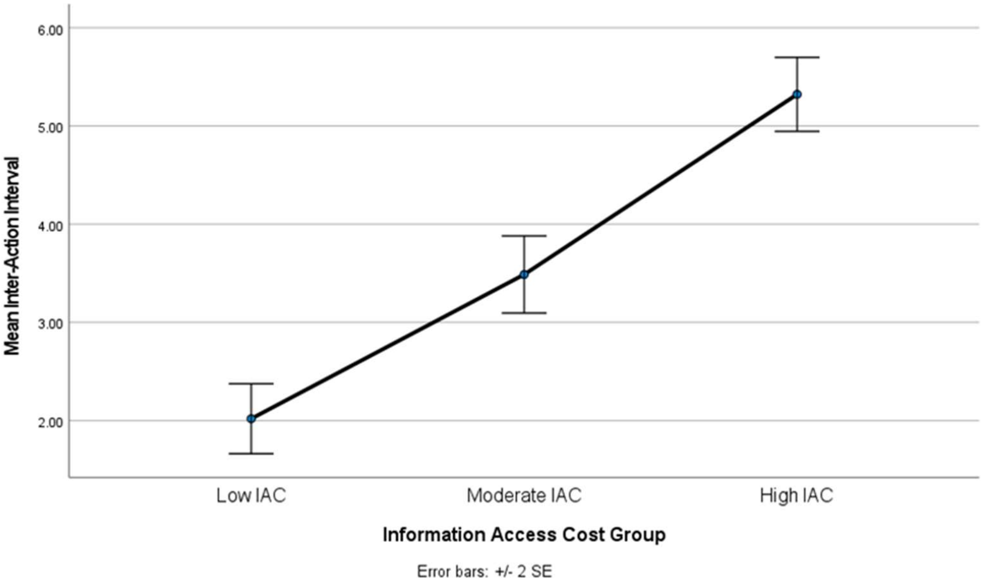


Figure 68 Inter-action interval across information access cost condition.

IAC and Interruption Complexity Analysis 6 - Comparison of post-interruption resumption lag (time between end of interruption and first response back onto primary task) compared to inter-action interval for interruption complexity and information access cost.

A mixed between and repeated analysis of variance (ANOVA) was used to evaluate the effects of information access cost (IAC: Low IAC, Moderate IAC, and High IAC) and interruption complexity (No Interruption, Low Complexity, Moderate Complexity, High Complexity) on the resumption lag in the CAMROSE Medication Pre-Administration Task. There was a significant main effect of interruption complexity on the resumption lag interval $F(2.08, 146.49) = 24.20$, MSE = 4.58, $p < .001$, $\eta^2_p = .249$ (Figure 69).

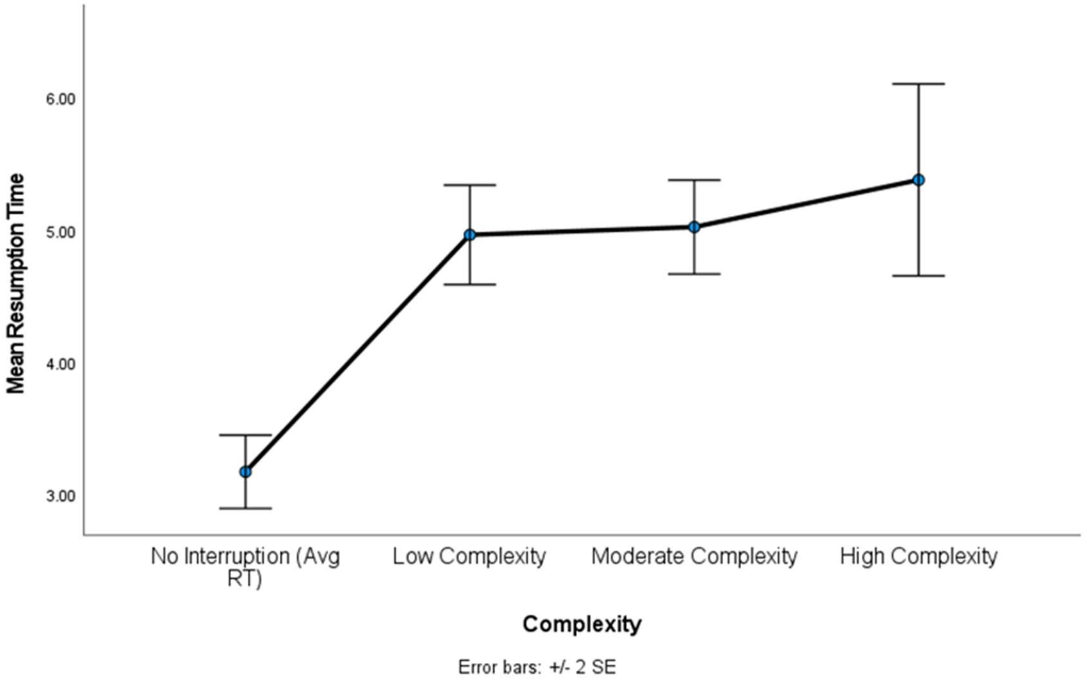


Figure 69 Resumption time across interruption complexity conditions in experiment 6.

Participants took longer to resume the primary task after an interruption in the low (M = 4.95, SE = .188), moderate (M = 5.01, SE = .178) and high (M = 5.37, SE = .363) complexity conditions compared to the average time to make a response in the no interruption condition (M = 3.16, SE = .138) with all *p's* <.001.

There was also a significant main effect of information access cost on the average time before resuming the primary task $F(2, 73) = 60.17$, MSE = 1.80 $p < .001$, $\eta^2_p = .622$ (Figure 70). Participants were on average significantly longer to resume the primary task as the information access cost increased from low (M = 2.57, SE = .254) to moderate (M = 4.68, SE = .280) to high (M = 6.62, SE .269) with all *p's* <.001.

There was no significant interaction between interruption complexity and information access cost of the time to resume the primary task after an interruption $F(4.01, 146.49) = 2.34$, MSE = 4.58 $p > .05$, $\eta^2_p = .060$.

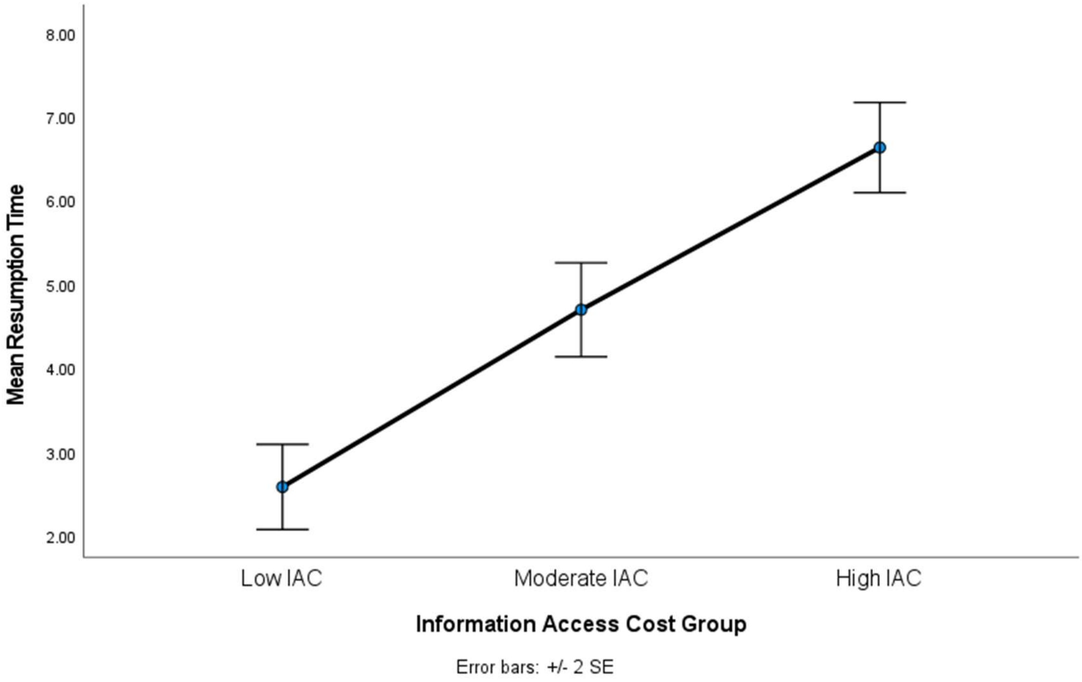


Figure 70 Resumption time across information access cost conditions.

A 2 (Response Type: Average Reaction Time, Average Resumption Lag) x 3 (IAC: Low IAC, Moderate IAC, High IAC) between and within mixed ANOVA was used to evaluate the differences between resumption lag and inter-action interval on each complexity condition across all the information access cost groups.

For the Low Complexity condition, results indicated that there was a significant difference in the average inter-action interval and resumption lag $F(1, 73) = 51.98$, MSE = 1.00, $p < .001$, $\eta^2_p = .414$ (Figure 71). Participants on average took longer to resume a task after a low complexity interruption (M = 4.95, SE = .188) compared to the average time to make a response (M = 3.78, SE = .155) $p < .001$.

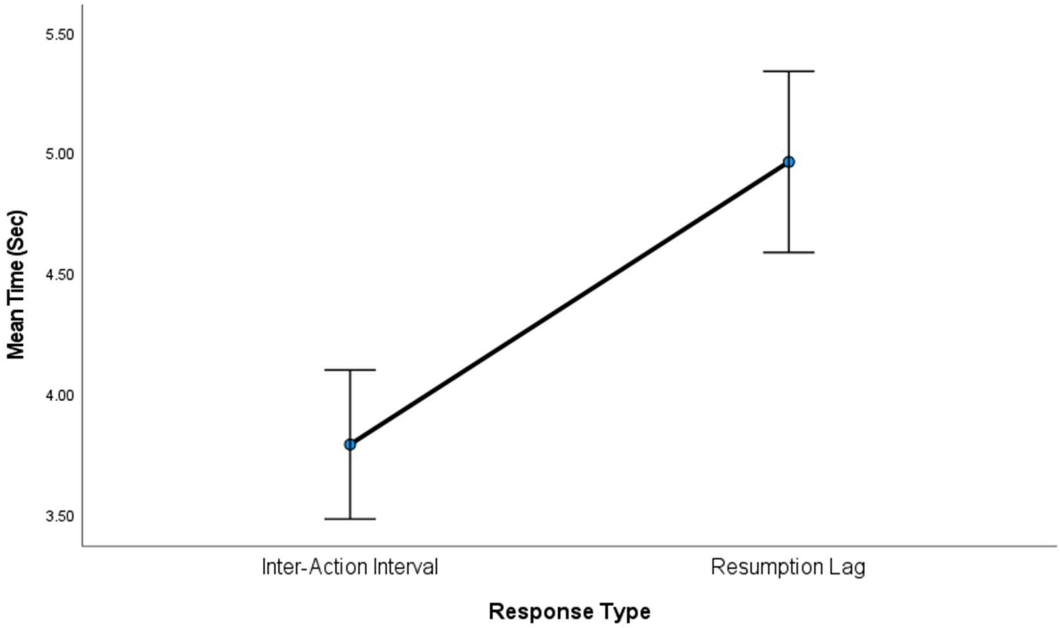


Figure 71 Comparison of inter-action interval and resumption lag in low complexity interruptions.

Furthermore, there was a significant difference between the responses across the information access cost groups in the low complexity conditions $F(2, 73) = 61.31$, MSE = 1.73, $p < .001$, $\eta^2_p = .627$ (Table 20). There was general trend in that across all the information access groups, the average time to resume a primary task was longer than the average time to make a response with all *p's* <.01.

Table 20 Comparison on inter-action interval and resumption lag across information access cost group in the low complexity interruption condition.

Information Access Cost Group	Response Type	Mean Time	Standard Error
Low IAC	Inter-Action Interval	1.98	.254
	Resumption Lag	2.77	.309

Moderate IAC	Inter-Action Interval	3.70	.280
	Resumption Lag	4.96	.341
High IAC	Inter-Action Interval	5.66	.269
	Resumption Lag	7.13	.327

Within the moderate complexity interruptions, there were significant difference between the inter-action interval and resumption lag $F(1, 73) = 73.28$, MSE = .932, $p < .001$, $\eta^2_p = .501$ (Figure 75). On average, the time to make a response when resuming the primary task after an interruption was longer (M = 5.01, SE = .178) than the average time to make a response (M = 3.67, SE = .123) p <.001.

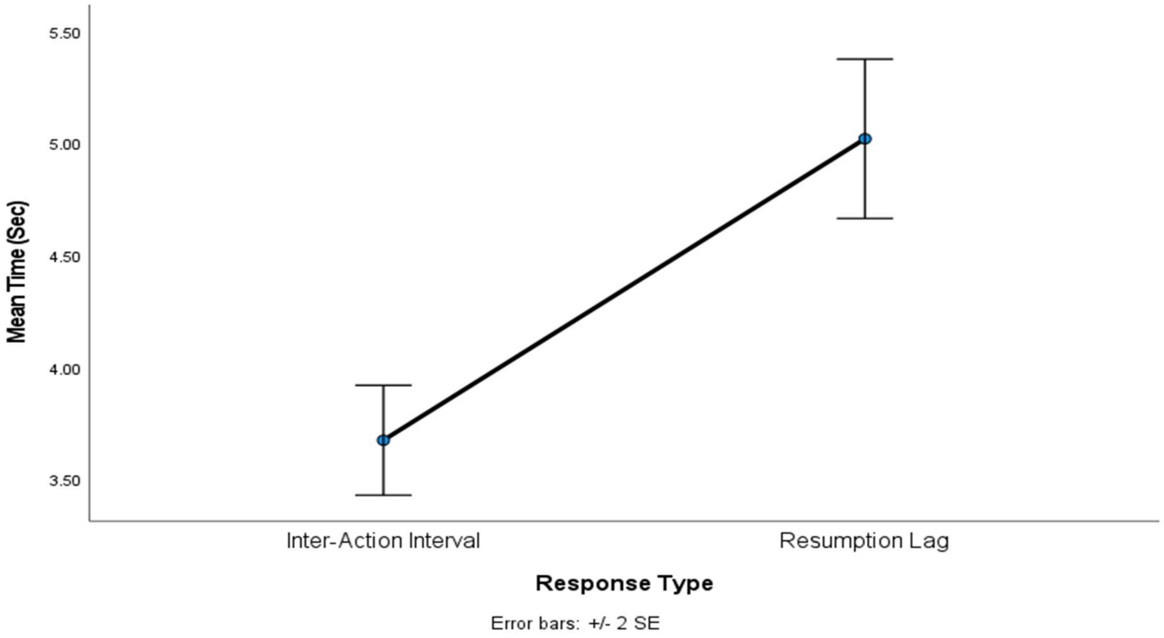


Figure 72 Comparison of inter-action interval and resumption lag in moderate complexity interruptions.

A similar trend to the low complexity was found in the moderate complexity interruptions in that across all information access groups, participants on average took longer to make a response after an interruption compared to the average response made with all *p's* <.01 (Table 21).

Table 21 Comparison on inter-action interval and resumption lag across information access cost group in the moderate complexity interruption condition.

Information Access Cost Group	Response Type	Mean Time	Standard Error
Low IAC	Inter-Action Interval	2.11	.201
	Resumption Lag	2.79	.292
Moderate IAC	Inter-Action Interval	3.45	.222
	Resumption Lag	4.93	.322
High IAC	Inter-Action Interval	5.45	.213
	Resumption Lag	7.32	.309

Within the high complexity interruptions there was a significant difference between the average time to make a response and the time to resume the primary task after an interruption $F(1, 73) = 49.58$, MSE = 91.85, $p < .001$, $\eta^2_p = .405$ (Figure 76).

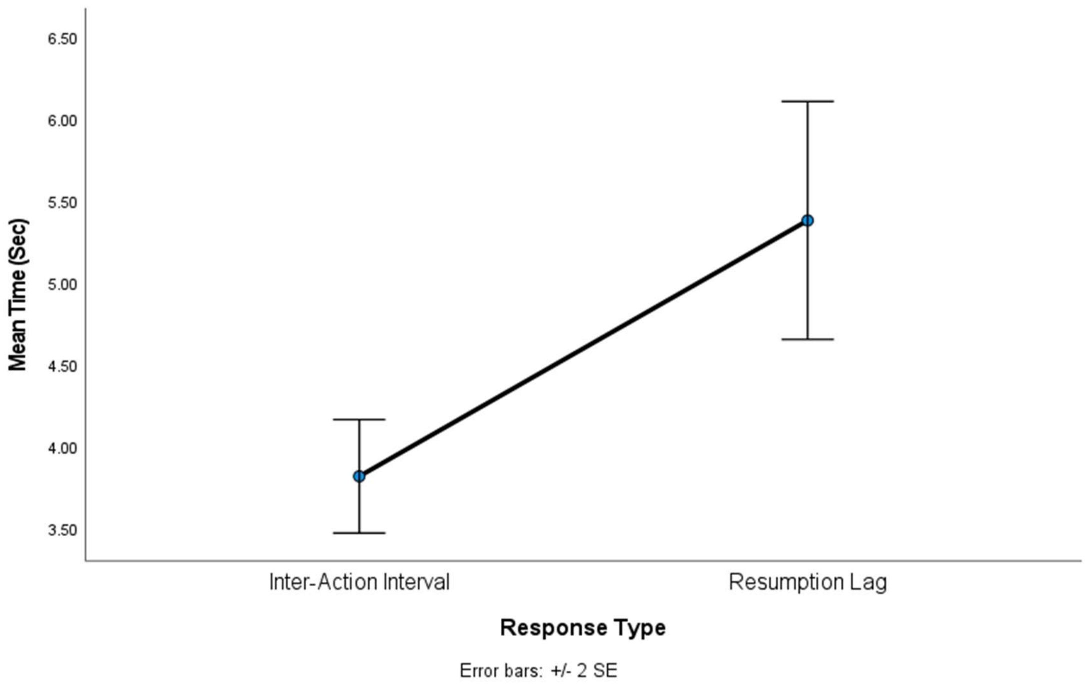


Figure 73 Comparison of inter-action interval and resumption lag in high complexity interruptions.

On average when the interruption complexity was high, participants took longer to resume the task after an interruption (M = 5.37, SE = .363) compared to the average response made (M = 3.81, SE = .173) *p* <.01.

Furthermore, the same trend as previous complexity conditions remained in that has the information access cost increased, participants took longer to resume the task compared to the average time to make a response with all *p's* <.05 (Table 22).

Table 22 Comparison on inter-action interval and resumption lag across information access cost group in the high complexity interruption condition.

Information Access Cost Group	Response Type	Mean Time	Standard Error
Low IAC	Inter-Action Interval	2.07	.284
	Resumption Lag	2.87	.595
Moderate IAC	Inter-Action Interval	3.70	.314
	Resumption Lag	5.76	.657
High IAC	Inter-Action Interval	5.66	.301
	Resumption Lag	7.53	.630

IAC and Interruption Complexity Analysis 7 - Comparison of interactions with user interface across interruption complexity and information access cost.

A 3 (Interruption Complexity: Low, Moderate, High Complexity) x 2 (Information Access Cost: Moderate, High Access Cost mixed between, and repeated measures ANOVA was used to explore various interface interactions. The first analysis explored differences in the average time participants spent on their first view of the CAMROSE task stimuli. Interruption complexity had no significant effect on the time spent on participants first visit of the stimuli $F(1.29, 59.43) = .489$, MSE = 16.93, $p > .05$, $\eta^2_p = .011$. Information access cost had significant effect on the time participants took on the first interaction with the stimuli $F(1, 46) = 6.23$, MSE = 37.90, $p < .05$, $\eta^2_p = .119$. On average participants spent longer viewing the experimental stimuli before making a response in the high information access cost group (M = 10.34, SE = 1.23) compared to the moderate information access cost group (M = 5.90, SE = 1.28) with $p < .05$ (Figure 74). Whilst participants spent longer viewing stimuli on their first visit, secondary analysis revealed no significant impact of complexity $F(2, 92) = .130$, MSE = 4.63, $p > .05$, $\eta^2_p = .003$ or information access cost $F(1, 46) = .042$, MSE = 86.52, $p > .05$, $\eta^2_p = .001$ on the number of time information was accessed. Furthermore, despite a trend in that less errors were made after the first interaction in the high IAC group compared to the moderate IAC group, this trend was not significant $F(1, 46) = 1.57$, MSE = .697, $p > .05$, $\eta^2_p = .033$ and interruption complexity did not have an effect either $F(1.72, 79.35) = .477$, MSE = .331, $p > .05$, $\eta^2_p = .010$.

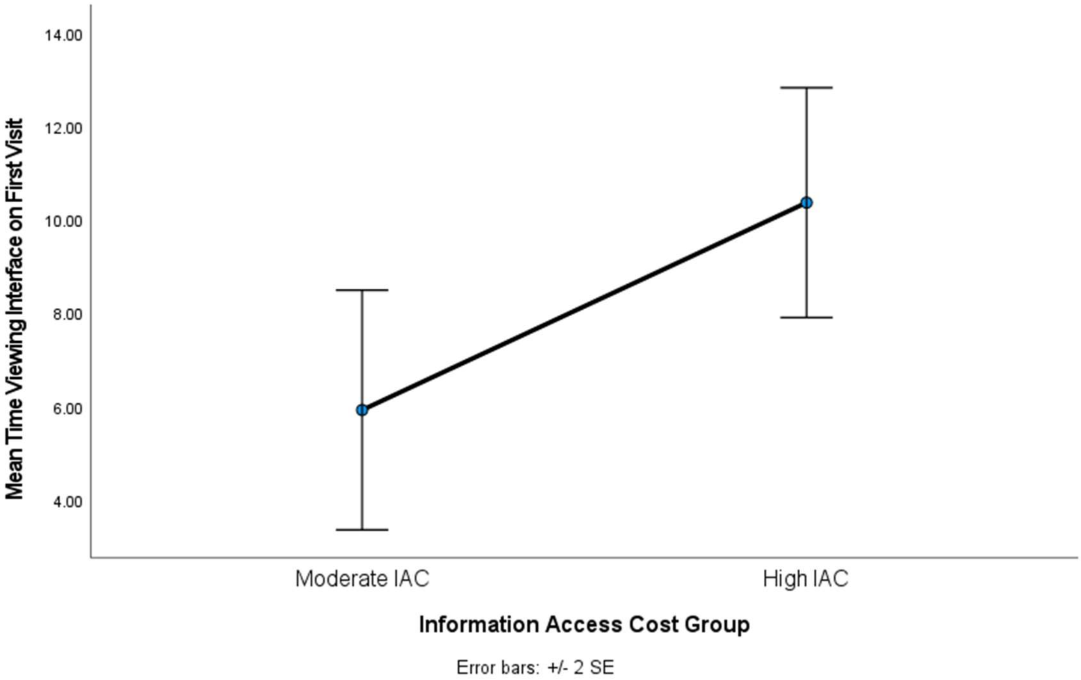


Figure 74 Average time view interface on first visit in information access cost conditions.

Summary

Sequence errors were more common under interruption conditions compared to the no interruption condition, and this trend held true across all three levels of complexity (low, moderate, and high).

The number of mistakes made in each sequence was significantly affected by how much it cost to access the information. The average number of sequence errors decreased as the cost of accessing information went up. In addition, compared to when the cost of accessing the information was low, sequence errors dropped dramatically when the cost of accessing the information was increased by 2 seconds. Thus, this lends credence to the second hypothesis. Complexity of interruptions interacted significantly with the price of gaining access to data. It was found that the third hypothesis was supported by the data, with fewer sequence errors occurring in higher interruption complexity and information access cost groups compared to comparative complexity groups with lower information access cost.

The number of mistakes made following an interruption upon resumption of the primary task did not change significantly based on complexity, information access cost, or interaction. There was a clear pattern where post interruption sequence errors increased with complexity and decreased with information access cost. Post-interruption non-sequence errors were unaffected by the complexity of interruptions, the cost of obtaining information, or the presence of interactions.

In the interrupted condition, participants took significantly longer to respond on average, regardless of the complexity of the task. As the conditional cost of accessing information increased, so did the time it took for participants to respond. When examining the impact of interruption complexity and information access cost on the inter-action interval, neither factor interacted significantly.

There was a statistically significant increase in the time it took to return to the primary task following an interruption, as compared to the average time it took to respond in the no interruption condition. Resuming the original task after an interruption took significantly more time as participants' costs to access information rose. Some significant effects were discovered when comparing the average inter-interaction interval with resumption time across complexity and information access cost. Participants took longer to resume a task after an interruption than the average time to make a response, even when interruptions were simple. When interruptions were simple, the average time to get back to work was longer than the average time to respond. This held true across all information access groups. The same held true for both less complex and more complex disruptions to the flow of information.

Chapter 7: General Overview

The purpose of this thesis was to deepen our understanding of task interruption by further exploring some of the issues raised by earlier studies of this phenomenon in safety-critical healthcare settings. In doing so, it opens the door for increased research into the causes and consequences of medication errors, as well as the development of strategies to reduce such errors in which task interruption is a contributing factor. The thesis provides a productive step in this area by addressing several crucial research questions that were formulated as a result of a thorough examination of the available literature. These included:

- Understanding the characteristics and perceived impact of task interruptions experienced by healthcare professionals in a hospital setting in the United Kingdom.
- Exploring how the context of the primary and interruption tasks may amplify the effect of commonly cited interruption characteristics (complexity, frequency, and interruption source) on performance.
- Understanding how the unique characteristics of safety-critical healthcare task interruptions (such as urgency and emotion) affect performance.
- Investigating the utility of computer-based interventions in mitigating the negative effects of task interruptions through promoting behavioural modifications.

Understanding the cognitive effects of interruptions on healthcare professionals can improve and/or extend the explanatory power of existing interruption theories and models, leading to more robust, cost-effective technological designs that offer flexible ways to effectively handle such interruptions within dynamic, safety-critical work settings. Though the information gained from past studies using conventional experimental tasks to probe the effects of interruptions on primary task outcomes has been helpful, how this data translates to actual clinical practice is still unclear. Using more realistic yet controllable tasks will improve the transferability of these findings, contribute to theories and models of task interruptions in an applied context, and pave the way for evidence-based interventions to mitigate the profound effects of such interruptions in clinical settings.

A systematic method was employed to both comprehend healthcare interruptions and help guide the construction of the experimental task and manipulations of interruption features for proceeding experiments. Recognizing the limitations of the existing literature, such as diverse operationalisation of task interruptions and minimal consolidation across disciplines about the advancement of research in this area, the first study aimed to address some of these limitations through a novel questionnaire administered to a sample of healthcare professionals in an Emergency and Critical Care setting in a UK hospital. By examining two forms of disruptions, interruptions and distractions, the study created an understanding of how healthcare professionals describe such notions and their view on interruption effects and critical characteristics. According to the results of this study, there is no universal agreement on what constitutes an interruption or a distraction by healthcare professionals. This can directly impact the perception of interventions proposed to reduce disruptive impacts (such as no interruption zones) which varies from healthcare professional to healthcare professional. A well-defined, context-specific, and consistent definition is required to support the implementation of interventions, or else interventions that do not depend upon different people's perceptions of disruptions and diversions are required (e.g., training in cognitive strategies). This study's findings on the frequency of medication-related task interruptions provide credence to the prevalence of the problem described in the aforementioned literature and highlight the pressing need to investigate this phenomenon further. In addition, the data showed that disruptions were most frequently caused by other medical professionals. This is to be expected, considering the complex structure of the healthcare environment and the importance of interpersonal relationships among healthcare workers.

Informed by the current clinical and theoretical literature on interruption as well as the results of the first study, a novel primary task, the CAMROSE drug pre-administration task, was developed for this thesis. CAMROSE is an abbreviation that depicts seven successive phases, with C being the initial step and AMROSE following. Each letter of the sequence corresponded to one of two possible responses for that step based on the information provided, and participants were required to choose the correct response. The task simulates the seven suggested checks required prior to administering medication. The CAMROSE task advances experimental task development. While it is important to have a primary task that is representative of those performed in a healthcare setting, for a better understanding of the interference effect of clinical task interruptions, these interruptions must match the characteristics of those most likely to occur in healthcare. In order to accomplish this, the task interruption simulated contextual components of the clinical environment. In general, the interruption task required participants to perform an adapted NHS Early Warning Score clinical decision-making test (NEWS). NEWS is a tool used throughout the NHS to examine patients' fundamental physiological indicators and to identify possible or established critical disease (Patterson, Maclean, Bell, Mukherjee, Bryan, Woodcock & Bell, 2011). In accordance with an

IF-THEN scenario initiated by a nurse confederate, participants were tasked with calculating a clinical score and determining the appropriate course of action. The interruption task's context was both familiar to a healthcare work environment and comprised task aspects that could be altered. The interruptions were created with the same level of accuracy in mind. Thus, trials were more accurate in imitating both the activities and interruptions that healthcare workers may face on a regular basis, allowing for a more comprehensive investigation of potential errors and actions that may prevent such errors.

Five experiments were conducted throughout the thesis to investigate both interruption characteristics that are commonly reported in the literature (e.g., complexity, frequency, and modality) and those that may be context-specific to healthcare settings (e.g., emotional valance and urgency). Focusing on commonly reported characteristics, taken together the findings differ to those often reported across past studies. In terms of interruption complexity, whilst there was a visible trend in more errors being made as complexity increased, interruptions only had to be low in complexity to have a significant impact on performance. The limited time available to rehearse the suspended task goals may be a reason for this (Cades, Trafton, Boehm-Davis and Monk, 2007). If dealing with the interruption is already seen as a challenging task, increasing, or decreasing the number of stages may not make much of a difference. It's possible that the fact that the participants weren't medical experts mediated this impact. The context's influence on performance is strengthened by this, though; if the context didn't affect performance, then the manipulation of complexity could be easier to evidence (e.g., Radovic & Manzey, 2022).

Interruption frequency significantly impacted performance when interruptions occurred at a high frequency (e.g., 60% of trials were interrupted). This can also be observed in post-interruption performance, where more errors and longer resumption times were occurring in the high frequency condition compared to the low and moderate. This is in-line with previous research (Speier, Valacich and Vessey, 1999; Monk 2002), however interruptions in this experiment did not place a time constraint on participants, and they did not occur in timed intervals rather were dictated by task position. This may suggest that regardless of the time interval between interruptions, and how long individuals spend, but rather conflict between perceived task characteristics and ability to prepare for subsequent procedural steps following an interruption. That is, it is more likely that mistakes will occur during the task if there is a disruption in the flow of information between the planning and execution phase (Trafton, Altmann & Ratwani, 2011). Given that significant effects were only identified at a high frequency (for low complex interruptions), it is possible that frequency and complexity have different effects on performance.

Findings about the source of interruptions showed that regardless of the type of interruption, tasks that were interrupted frequently experienced sequence errors. Despite having more sequence errors than face-to-face or telephone interruptions, email interruptions were not significantly different from them. Furthermore, after the email and face-to-face conditions, the time to return to the main task was longer, whereas it was shorter after the phone condition. Compared to face-to-face and telephone interruptions, the number of post-interruption errors after an email interruption increased significantly. It could be argued that emails were more time-consuming than sources where information is just given (such as face-to-face interactions and phone calls; Kahneman, 1973) because they required an action (reading the email, for example), which left fewer resources available to practise primary task objectives. The interruption might have been prolonged by the email, and this possibility should be further considered as either a potential cause of effect or contributing factor (Labonte & Vachon, 2021).

After examining the general characteristics of task interruptions, the goal of the thesis was to gain a deeper understanding of the effects of particular interruption characteristics of a healthcare environment in the form of emotional valence and urgency. Emotional valence significantly affected post-interruption sequence errors. Interestingly, participants made more post-interruption sequence errors when the interruption had a positive valence compared to negative or neutral valences. In some ways, these findings diverge from what is suggested by the literature. Other research has found that the dissimilarity of the interruption's content can amplify the interruption effect, and that both negative and positive emotions have an effective and increasing effect on performance if the task is emotionally significant (Speier et al., 1999). Two studies back up this claim (Anderson & Phelps, 2001; Vuilleumier, 2005). Because of the nature of the healthcare setting, it could be argued that any emotional cue would be helpful; however, if this were the case, we would not expect to find any effect of emotional valance on performance, which was not the case here. These findings were replicated within the following experiment when also exploring interruption urgency. One possible reason might be linked to the perceived difficulty of the task in these trials, in conjunction with the fact that positive stimuli capture attention more effectively under high task load (Gupta, Hur & Lavie, 2016). This logic suggests that positive disruptions attract attention more than negative interruptions, making it difficult to recall suspended task goals. In addition, when interruptions were urgent, participants made significantly more mistakes than when they were less urgent. Post-interruption sequence errors showed similar trends, with more errors occurring on average when interruptions were urgent than when they were not. Findings within the urgency conditions could be interpreted in relation to the distribution of sequential control, in that the fast nature of urgent interruptions displaced the held task step in memory resulting in a quicker decay of primary task goals (Altmann, Trafton & Hambrick, 2014).

The final experiment explored the utility of a novel intervention that could inform more robust, cost-effective technological designs, and offer flexible ways to effectively handle task interruptions within dynamic safety critical work settings. This involved utilising the predictions made within the Theory of Soft Constraints in that increasing information access cost will encourage a more intensive memory-based approach (Gray & Fu, 2004; Gray et al., 2006). Findings inform a positive step towards understanding how to mitigate the negative effect of interruptions in dynamic environments. Sequence errors were significantly affected by how much it cost to access the information. The average number of sequence errors significantly decreased as the cost of accessing information went up. In addition, compared to when the cost of accessing the information was low, sequence errors dropped dramatically when the cost of accessing the information was increased by 2 seconds. There was also an interaction effect present in that the number of errors decreased as the complexity of interruptions went up and cost of accessing information was high. Specifically, participants employed more memory-intensive strategies to mitigate accessing the required information, and in doing so, they strengthened task goals when interrupted, leading to less decay, consistent with the predictions made in terms of information access cost. Extending previous reports, this study found that increasing the cost of accessing information mitigated the detrimental effects of interruptions to performance (Morgan & Patrick, 2013). Information access costs extend to enhance sequential performance on a high-fidelity experimental task, in addition to the previously reported enhancements in memory recall (Morgan et al, 2009) and problem-solving efficiency (Waldron, Patrick & Duggan, 2011). The extra memory-based planning that is induced under high information access cost conditions may be to blame for this, as it strengthens individuals' goals or sub-goals for the sequence.

Current literature indicates a lack of a direct link between theoretically informed findings on the characteristics of clinical task interruptions that could underlie their disruptiveness. However, it does provide valuable insights into the role of interruptions and capture the complexity of trying to understand interruptions in dynamic working environments like healthcare. To further the field of research it is crucial that researchers across disciplines work together to bridge this gap through theoretically informed studies employing tasks (primary and interrupting) with some degree of ecological validity. This thesis provides an initial step towards this, through developing novel and high-fidelity experimental tasks (the CAMROSE Medication Pre-administration task, and Clinical Decision-Making Task) that has allowed for further understand of the nature of task interruptions in healthcare. In doing so, it has allowed for the exploration of novel interventions that not only minimises the burden of task interruptions, but has potential to be flexible when implemented in complex socio-technical environments such as healthcare. Previous experimental studies have attempted to generalise their findings to healthcare settings, especially when the focus of the research is on tasks that best represent well-learned skills and procedures (like procedural memory: Altmann et al, 2014) assumed to mimic tasks/subtasks in some settings. Both the primary task and the interruption task in many of these studies lack domain-specific content that would better capture the varying properties such clinical tasks may have, despite the fact that such tasks may represent elements (e.g., a sequential procedure) of clinical tasks that follow similar processes (e.g., medication administration) (McCurdie, Sanderson & Aitken, 2017). The thesis has made significant contributions to this current literature through extrapolating results to the context that the experiments are meant to probe (e.g., healthcare medication administration), thus providing additional utility when considering designs that are representative of that context. More accurately reflecting individuals' functional behaviours in the wild allowed for some complexity, novelty, and diversity across all experimental conditions rather than overcontrolling them (Ajaujo, Davids & Passos, 2007).

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Appendices

Appendix 1 – Survey Interruptions and Distractions in Emergency and Critical Care Work Settings

Interruptions and Distractions in Emergency and Critical Care Work Settings

Thank you for volunteering to participate in this study that will form an important part of a PhD research project being conducted by Craig Williams at the University of the West of England - Bristol. The following questionnaire has been designed to investigate the propensity, nature, and effects of interruptions and distractions in a variety of emergency and critical care settings. First, you will be expected to complete some demographic questions. **Section 1a** will focus on clinical ***task interruptions and distractions*** and contains a serious of questions relating to your experiences of interruptions and distractions within your workplace setting(s). **Section 1b** gives you an opportunity to reflect on two (one positive and one negative) critical events involving interruptions and/or distractions.

Each section of the questionnaire is important for the understanding of the research questions and should take no longer than **30 minutes** to complete. However, if you wish to only complete Section 1a this will take no longer than **15 minutes** to complete. At the end of Section 1a you will be given an option to complete Section 1b, if you chose **'NO'** it will redirect you straight to the debrief of the study.

Before we begin, please provide below a brief description of your understanding of what constitutes an interruption and distraction?	
Interruption	Distraction

Participant Code (Please provide a unique password that can only be identified by yourself consisting of the last two letters of your first name, your year of birth, and first two letters of your surname (e.g., IG1988WI).
Date Completed: Day: Month: Year:

Demographic Questions

What is your age? (Please provide in years and months).	**What is your gender? (Male, Female, Other, or Prefer not to say).**	**Please specify your ethnicity origin (e.g., White, Hispanic, or Latino, Black, Asian, Mixed ethic group (please specify), Other).**	**What is your highest qualification relating to your current job (e.g., Undergraduate diploma/degree, Postgraduate diploma/ degree, Master's degree, Doctoral Degree, PhD, Other)?**	**What is your highest qualification (e.g., Undergraduate diploma/degree, Postgraduate diploma/ degree, Master's degree, Doctoral Degree, PhD, Other)?**

What is your current job position, including the clinical area you mainly work within (e.g., Staff Nurse, Band 5, Intensive Care Unit)?	**How long have you worked in your current position (please provide in years and months)?**	**What are your contracted work hours per week?**	**On average, how many hours a week do you work?**	**How long have you worked within an Emergency and/or Critical Care setting (including your current post)?**	**How long have you worked within a hospital setting (including your current post)?**

Section 1a - Interruptions and Distractions in Emergency and Critical Care

Interruptions often refer to the reallocation of cognitive resources to a secondary stimulus, which requires the individual to suspend the current task at hand and shift their attention to a secondary task. For example, a nurse doing a drug-ordering task is asked to help with the finding of some medical equipment. Therefore, the drug-ordering task is suspended, and attention is shifted to finding medical equipment.

Distractions refer to background stimuli which are often (but not always) intended to be ignored. For example, whilst a nurse is completing a drug-ordering task, two healthcare staff are having a conversation about their rotas for the following week. The conversation is irrelevant to the nurse experiencing the distraction, so they must try to maintain a focus on the drug-ordering task whilst trying to ignore the background conversation.

Please refer to the above definitions when completing the following questions on interruptions and distractions and look back at them whenever you feel the need to do so.

Q1 – Of the clinical task interruptions and distractions you have experienced, what clinical tasks do you feel are interrupted and distracted the most. ***Please list below the 3 common clinical tasks you feel are interrupted and distracted the most, starting with the most common.***

CLINICAL TASK INTERRUPTED	CLINICAL TASK DISTRACTED
First most common:	First most common:
Second most common:	Second most common:
Third most common:	Third most common:

Q2 – Below is a list of potential sources of interruptions and distractions. Based on your experience of clinical task interruptions and distractions, using the rating chart below, please indicate on average how often you feel clinical tasks are interrupted and distracted by these sources. ***Please put one response number for each source for both interruptions and distractions using the below rating chart.***

Rating Chart	
1	**Never** interrupted or distracted by this source
2	**Rarely** interrupted or distracted by this source
3	**Sometimes** interrupted or distracted by this source
4	**Often** interrupted or distracted by this source
5	**Almost always** interrupted or distracted by this source

Source	**Interruptions**	**Distractions**
Administration Staff		
Nurse		
Doctor		
Anaesthetist		
Paediatrician		
Other Clinical Staff (e.g., Consultant, Radiologist, Surgeon)		
Non-Clinical Staff (e.g., cleaner, security, porter)		
Department Telephone (e.g., stationary or mobile department phone)		
Personal Mobile Telephone		
Computer Related (e.g., ability to use a clinical computer application, computer failure, accessibility, speed of computer, pop up notifications)		
Clinical Equipment (e.g., knowledge of use, equipment failure, accessibility)		

Email		
Beeper (e.g., pager)		
Visitor (e.g., patient relatives)		
Patient (e.g., patient background conversations whilst performing a clinical task, patient seeking advice during the writing up of clinical notes)		
Self (e.g., remembering to go back to an unfinished task, thinking about information not relevant to the task at hand)		
Alarms (e.g., emergency alarms, fire alarms, patient bedside alarms)		
Other – Please Specify Below (up to five)		

Q3 – From your experience of clinical task interruptions and distractions, what are the most common reasons for the interruption or distraction? ***Please list below the 3 most common reasons you feel clinical tasks are interrupted or distracted, starting with the most common.***

REASON CLINICAL TASK IS INTERRUPTED	REASON CLINICAL TASK IS DISTRACTED
First most common:	First most common:
Second most common:	Second most common:
Third most common:	Third most common:

Q4 – Of the clinical task interruptions and distractions you have experienced, on average, how often do you feel that they are relevant or irrelevant to the clinical task you are performing? ***Please provide below a separate answer for both interruptions and distractions using the scale 0 (Never) – 100 (Always).***

	Interruptions relevant to the current clinical task	**Interruptions irrelevant to the current clinical task**		**Distractions relevant to the current clinical task**	**Distractions irrelevant to the current clinical task**

Q5 – ***Please list below*** the time and hours of all typical shift patterns you may work, and rate how often you may be interrupted and/or distracted during this shift using the rating chart below.

Rating Chart	
1	**Never** interrupted or distracted during this shift
2	**Rarely** interrupted or distracted during this shift
3	**Sometimes** interrupted or distracted during this shift
4	**Often** interrupted or distracted during this shift
5	**Almost always** interrupted or distracted during this shift

Shift Pattern	**Interruptions**	**Distractions**
Example 1: 07.00 – 19.00 (12 hours)	**4**	**3**
Example 2: 13.00 – 21.00 (8 hours)	**2**	**3**

Q6 – Are there periods within the typical shift patterns you have indicated above, where you feel clinical tasks are interrupted or distracted the most? ***Please indicate the estimated time, the number of clinical task interruptions and/or distractions you are likely to experience, and any other details that you feel are relevant to this time.***

Time	**Amount of interruptions (estimate)**	**Amount of distractions (estimate)**	**Details**
Example: 07.00 – 08.00	**5**	**6**	**Handover period**

Q7 – From your experience of clinical task interruptions and distractions, how do you feel they have affected you? **Using the below rating chart, please indicate how often this effect is likely to occur for interruptions and distractions, and where asked please give an example. Please note that some effects are only related to interruptions, but not distractions. Where this is the case, the distraction box will be blanked out (in black), and only one answer will be required.**

Rating Chart	
1	**Never** experience this effect when interrupted or distracted
2	**Rarely** experience this effect when interrupted or distracted
3	**Sometimes** experience this effect when interrupted or distracted
4	**Often** experience this effect when interrupted or distracted
5	**Almost always** experience this effect when interrupted or distracted

Effect	**Interruptions**	**Distractions**	**Example (if asked)**
Time delay in the resumption of the interrupted clinical task		■	
Longer than usual to complete the clinical task.			

Forgetting to resume the interrupted clinical task (e.g., not returning to the interrupted clinical task)			
Forgetting/missing/overlooking of information related to the clinical task at hand **(Please give an example of the type of information you may forget)**			
Increased stress			
Increased fatigue			
Increase in ability to deal with multiple pieces of information			
Decrease in ability to deal with multiple pieces of information			
Increase in work efficiency **(Please give an example of increased work efficiency that may occur)**			
Decrease in work efficiency **(Please give an example of decreased work efficiency that may occur)**			
Error in the process for the clinical task (e.g., continuing the task at a point different to where you left it, forgetting a task step)			
Minor error **(Please give an example of the type of minor error that may occur)**			
Moderate error **(Please give an example of the type of moderate error that may occur)**			
Major error **(Please give an example of the type of major error that may occur)**			

Other – Please specify (up to five)			

Q8 – Some techniques have been proposed that aim to aid in the handling of interruptions and distractions. ***Using the tables below, please indicate how often you have used these techniques during clinical tasks, and how effective or ineffective you feel they are for handling interruptions and distractions.***

Rating Chart	
1	**Never** use this technique for handling interruptions or distractions
2	**Rarely** use this technique for handling interruptions or distractions
3	**Sometimes** use this technique for handling interruptions or distractions
4	**Often** use this technique for handling interruptions or distractions
5	**Almost always** use this technique for handling interruptions or distractions

Effective Chart	
1	**Very ineffective** in handling interruptions or distractions
2	**Somewhat ineffective** in handling interruptions or distractions
3	**Neither effective or ineffective** in handling interruptions or distractions
4	**Somewhat effective** in handling interruptions or distractions
5	**Very effective** in handling interruptions or distractions

	Used to handle interruptions	**Used to handle distractions**	**Effective/ineffective for handling interruptions**	**Effective/ineffective for handling distractions**
Example – Note Taking	**2**	**2**	**0**	**0**
No/minimal interruption/distraction zone (e.g., quiet zone)				
'Do not interrupt/distract' clothing (e.g., fluorescent vests)				

‘No interruption/distraction’ advertisements (e.g., posters, signs, cones)				
Diversion strategies (e.g., pre-arranging for other staff to attend to non-emergency interruptions)				
Process strategies (e.g., checklists to aid a process)				
Memory strategies (e.g., keep notes to aid resumption)				
Use of technology (e.g., visual cues to aid resumption)				
Interruption handling strategies (e.g., prioritising)				
Other – Please specify (up to five)				

Do you wish to continue onto Section 1b? Please select one of the answers below.	
Yes, I would like to continue onto Section 1b.	
No, I would like to be redirected to the debrief.	

Section 1b – A Critical Incident Example of Interruptions or Distractions in Emergency and Critical Care

Within this section, you are given the opportunity to freely reflect on **TWO** critical incidents involving an interruption(s) and/or distraction(s), and provide a detailed, confidential reflection of what happened, why it happened, and the outcome of this critical incident. You will be asked to complete two critical incidents, which has either led to an ineffective (negative) outcome, or led to an effective (positive) outcome. You can also choose whether you wish to reflect on an incident involving an interruption or distraction for both the ineffective and effective critical incidents. When completing this section, please ensure that you do not use any names of staff or patients, or any information that may lead to the direct identification of an individual, including yourself. Furthermore, please do not provide any details of the hospital the incident occurred at.

Remember, **i**nterruptions often refer to the reallocation of cognitive resources to a secondary stimulus, which requires the individual to suspend the current task at hand and shift their attention to a secondary task. For example, a nurse doing a drug-ordering task is asked to help with the finding of some medical equipment. Therefore, the drug-ordering task is suspended and attention is shifted to finding medical equipment.

Distractions refer to background stimuli which are often (but not always) intended to be ignored. For example, whilst a nurse is completing a drug-ordering task, two healthcare staff are having a conversation about their rotas for the following week. The conversation is irrelevant to the nurse experiencing the distraction, so he/she must try to maintain a focus on the drug-ordering task whilst trying to ignore the background conversation.

When you are ready, please turn over to begin.

Ineffective Critical Incident

Please circle below if the ineffective incident involves an interruption or distraction.

Interruption **Distraction**

Describe what happened.
Why was this ineffective?

What was the outcome of this ineffective incident involving an interruption or distraction?

Effective Critical Incident

Please circle below if the effective incident involves an interruption or distraction.

Interruption **Distraction**

Describe what happened.
Why was this effective?

What was the outcome of this effective incident involving an interruption or distraction?

Now that you have completed the set questions within this questionnaire, we would like to give you an opportunity to share any additional information in relation to clinical task interruptions and distractions. Please use the boxes below to describe any additional information.

Is there anything else you would like add about clinical task interruptions?

Is there anything else you would like to add about clinical task distractions?