

Abstract

This article seeks to place children on the autism spectrum at the centre of a study examining the potential of virtual reality head-mounted displays used in classrooms. In doing so we provide data that addresses three important and often overlooked research questions in the field of autism and technology; working in school-based settings with 31 autistic children from 6-16 years of age. Firstly, what type of VR HMD device (and experiences therein) are preferred by children on the autism spectrum using head-mounted displays (given possible sensory concerns). Secondly, how do children on the autism spectrum report the physical experience, enjoyment, and potential of VR HMDs in their classrooms? Finally, we were interested in exploring what children on the autism spectrum would like to use VR in schools for? Through a mixed methods approach we found that costly and technologically advanced HMDs were preferred (namely: HTC Vive). In addition, HMDs were reported as being enjoyable, physically and visually comfortable, easy to use, exciting and children wanted to use them again. They identified several potential usages for HMDs, including; relaxing / feeling calm, being able to explore somewhere virtually before visiting in the real world and to develop learning opportunities in school. We discuss these findings in the context of VR in classrooms in addition to considering limitations and implication of our findings.

Using virtual reality head-mounted displays with autistic children: views, experiences and future directions.

Introduction

Virtual reality (VR) is a term that has been used to describe a range of technologies developed since the 1960s including virtual worlds (VWs), massive multiplayer online role-playing games (MMORPGs), virtual environments (VEs), collaborative virtual environments (CVEs), and head-mounted displays (HMDs). One vital and definitional property of all forms of VR, including its presentation via HMDs, is the condition of presence. This means that coupled with input devices (gloves, controllers, trackers) and state-of-the-art graphics, VR HMDs can reflect real world scenarios and activities with a high degree of fidelity and realism [1, 2]. This is one reason they have been used in education and for a wide range of other disciplines such as neurocognitive assessments, psychotherapy, psychology, rehabilitation, communication training, simulations training and vocational training [1]. With a growing range of affordable devices available for different experiences (see [1] for an overview), there is a timely and urgent need to engage with user groups (and other stakeholders) to ascertain their views and experiences of VR HMDs.

Autism and Virtual Reality

Autism is a lifelong developmental condition that affects how people perceive, communicate and interact with the world. Autistic¹ people share common areas of difference, but as a spectrum condition being autistic will affect individuals in

¹ In line with the preferences of the UK autism community, the terms 'on the autism spectrum' or 'autistic person/people' will be used rather than 'person with autism' to represent identity first language Kenny et al., (2016).

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different ways. Some autistic people also have learning disabilities or co-occurring conditions (i.e. ADHD, down syndrome and epilepsy). Around 1 in 59 children have been identified as being on the autism spectrum according to current estimates from CDC's Autism and Developmental Disabilities Monitoring (ADDM) Network [3]. Within the UK, figures from the Department of Education show the number of children and young people who have autism as their primary special educational need (SEN) has increased year on year from 66,195 in 2011/12 to 100,010 in 2015/16. This means that children and young people on the autism spectrum accounted for 1.17% of the total school population in England.

Despite some initial positive outcomes, the use of VR HMDs with autistic groups has remained under-researched since initial studies were conducted in the 1990's [4, 5]. This was mainly due to the size, cost, applicability and real-world potential of HMDs during this time. More recently, there has been renewed interest in the possibilities of this technology to support the education of students on the autism spectrum. For example, Parsons and Cobb [6] suggest that VR can: "*offer particular benefits for children on the autism spectrum, chiefly because it can offer simulations of authentic real-world situations in a carefully controlled and safe environment*" (p. 355). However, Parsons and Cobb's review does not specifically include HMDs. This technology (HMDs), we suggest, offer another level of "representational understanding" in addition to providing further questions related to acceptability (i.e. sensory concerns of wearing a device; see [5] for a more detailed review).

There has been some work concerned with addressing questions of acceptability and usability of HMDs with autistic groups. The work of Newbutt et al. [7] provides details related to the acceptability of HMDs used by autistic people in addition to

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examining sense of presence, immersion and any negative effects (i.e. dizziness, feeling sick, eye strain). This research showed HMDs to be an acceptable and usable fit for a range of autistic users; before which there was little, if any, evidence to support the case for using HMDs with autistic groups.

While VR HMDs have been used by autistic groups for several years and across several studies [5], there still remains a lack of focus and work placing autistic people at the core of this research field; ascertaining the views of autistic people and their experiences and preferences for VR HMDs. In addition, and despite the possible potential of VR HMDs for autistic populations, very little research has been conducted within educational settings or with younger children on the autism spectrum. Moreover, limited data relate to the types of VR HMDs that are most suitable and preferred by autistic groups, or by younger people in schools more broadly. Therefore, the aim of the present study was to investigate three aspects that will offer new and novel insights to use of VR HMDs by children on the autism spectrum in school settings. These three aspects of investigation create the following research questions for the study:

1. What type of VR HMD device and experiences therein are preferred by children on the autism spectrum?
2. How do children on the autism spectrum report the physical experience, enjoyment, and potential of VR HMDs in their classrooms?
3. What would children on the autism spectrum like to use VR for in schools?

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These questions will contribute to the development of effective use of VR HMDs by autistic children and their teachers and reveal ways in which HMDs could be suitably applied in classrooms for this specific population.

Methods

Participants and Settings

We worked across four schools with n=43 children; n=31 of whom were autistic, in gathering data related to our research questions. The schools were conveniently selected dependent on the research team having existing contacts with them and were all located in the UK in South West and South East England. Table 1 provides an overview of each school, identified as school A, B, C and D, to maintain anonymity.

*** INSERT TABLE 1 ABOUT HERE ***

We worked directly with autistic children in all participating schools. Please note that Table 2, below, identifies the number of autistic children we worked with in mainstream settings, and all subsequent reported data represent autistic children only due to the focus of the current study. We worked across an age range and with males and female individuals and a total of n=31 autistic children. Table 2 presents the demographics of children we worked with across the four schools (with autistic data separated out).

*** INSERT TABLE 2 ABOUT HERE ***

Materials: Virtual Reality Head-mounted Display Technology Used

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The technologies used were selected as they represent current (as of mid-late 2018) affordable usable HMDs on the market. They were also selected as a range to help assess high-mid-low technology examples of VR HMDs. They each had limitations, qualities and differences. For example, the HTC Vive is considered a “high-end” device and as such promotes superior 3D graphics, is comfortable to wear and provides a complete immersive experience. However, it requires specialist and specific hard/software knowledge to manage and run. On the other hand, the smartphone with Google Cardboard option is far less expensive and more accessible to use but provides less immersive experiences employing graphics that are less life-like. Figure 1 illustrates what the HMDs looked like, while table 3 provides further details of the equipment used in this study.

*** INSERT FIGURE 1 ABOUT HERE ***

*** INSERT TABLE 3 ABOUT HERE ***

Design and Ethics

Given the differing cognitive, sensory and perceptual profiles of autistic children and the lack of studies examining HMDs with autistic groups, we carefully considered ethics; ensuring the safety of participants was paramount to us. Therefore, this study sought and achieved full ethical approval from the University Faculty Committee in addition to working closely with the schools to ensure ethical frameworks were developed and adhered to. Part of the ethical processes involved careful consideration related to working with younger children (i.e. <13 years) and VR HMDs. While there are several guidelines set by HMD providers related to devices being used by children

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> 13 years of age, there is currently limited evidence to support why this age has been set. However, some research suggests that “*HMD[s] should be used with caution because of its detrimental impact on dynamic balance*” [8; p. 261]. With this in mind, we developed a clear and careful way of working with younger populations (mean age = 12, age range = 6 to 16). What this meant was ensuring that both teachers and the researcher was always present during HMD use and checking for any possible negative effects or problems with the HMD use at regular intervals. This was in addition to providing seating and regular breaks in exposure (2-3 min. use at a time). We also carefully selected the applications (apps) to best ensure a pleasant and appropriate environment for the young users. Figure 2 highlights what the interfaces looked like for each of the VR HMD experiences. As can be seen in Figure 2, interfaces on the HTC Vive were computer generated, while 360-degree video examples were used on the Class VR and cardboard VR HMDs. The apps were selected in consultation with staff at the schools and agreement about which ones to use.

*** INSERT FIGURE 2 ABOUT HERE ***

In working in a careful and ethical way with users, we developed a process to help identify possible or foreseeable problems. We did this, in part, in recognition of the safety guidelines some HMDs provide for younger users (i.e. <13 years of age). This relates to the development of their visual apparatus and possible issues therein; despite there being limited concerns with adult populations [15] work with younger populations remains under-explored. However, by working carefully, responsibly and in consultation with the users we established ways of working so that the Ethical

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Review Committee was happy to approve this study. Figure 3 captures this process and provides the way we endeavoured to ensure the safety of the users using VR HMDs.

*** INSERT FIGURE 3 ABOUT HERE ***

Procedure

Having designed a clear ethical procedural framework, as described above, working in collaboration with teachers, we next sought to identify and describe the insights and experiences reported by autistic children using the VR HMDs. This process involved the steps described in Table 4, below.

*** INSERT TABLE 4 ABOUT HERE ***

Data Collection and Analysis

In addressing our research questions, we devised questionnaires as a primary source of data collection. These were designed in to gain insights to the usefulness of VR, enjoyment, physical experiences, and desire to use them in the future. The questions were designed with a Likert-type scale which was appropriate as we were seeking opinions about a specific topic in a quantifiable format. We chose a scale of one to four (1=do not like it at all; 2=Was okay but felt uncomfortable; 3=It was good, I liked it; 4=liked it very much). We removed the typical “not sure” option to help ensure the children would commit to a response indicating a preferred option. Teachers helped, where appropriate, to articulate the questions (and meaning therein) to children who struggled to fully understand what was being asked while the

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question format was designed to facilitate understanding by the participants. Figure 4 provides an example of how the questionnaire was designed and presented to the participants, while Table 5 provides the link between our research questions and data that were gathered to help address / answer them.

*** INSERT FIGURE 4 ABOUT HERE ***

*** INSERT TABLE 5 ABOUT HERE ***

During analysis, questions were organised into three categories. These were designed to best capture data associated with our research questions. The categories were as follows: (C1) usefulness and enjoyment; (C2) physical experiences and; (C3) use again/recommend to others. Table 6 highlight the categories and the questions that were used to generate these.

*** INSERT TABLE 6 ABOUT HERE ***

Results

Research Question one

This question identified preference of device based on the participants' experience of using each device for between 5 and 10mins. By asking their views on the most and least enjoyable device we report the results in Table 7.

*** INSERT TABLE 7 ABOUT HERE ***

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Results clearly highlight a preference towards the HTC Vive across each of the four schools. This finding is also coupled with data suggesting that the ClassVR HMD was the least preferred device. The smartphone used with a cardboard HMD was in a few cases the preferred device.

Research Question two

This question sought to address how autistic children report the physical experience, enjoyment, and potential of VR HMDs in their classrooms. To achieve this, the questions were presented to each participant after they had the chance to experience each of the VR HMDs used in this study.

After experiencing the HMDs the questionnaire was administered and responses gathered. Figure 5 shows the mean calculated across the categories for each of the schools (1 – 4). Data for the first category (enjoyment/usefulness) highlighted high enjoyment across each of the schools. School 1 reported a mean = 3.78 ($SD = 0.13$); school 2 = 3.67 ($SD = 0.33$); school 3 = 3.54 ($SD = 0.32$); school 4 = 3.67 ($SD = 0.07$). Category 2 elicited a similarly positive view related to physical experience with school 1 reporting a mean = 3.79 ($SD = 0.06$); school 2 = 3.67 ($SD = 0.47$); school 3 = 3.75 ($SD = 0.09$); school 4 = 3.63 ($SD = 0.00$). Finally, category 3, related to using the VR HMD again and recommending to others captured the most positive response across the schools with school 1 reporting a mean = 3.94 ($SD = 0.10$); school 2 = 3.89 ($SD = 0.19$); school 3 = 3.88 ($SD = 0.10$); school 4 = 3.79 ($SD = 0.07$).

Research Question three

The final research question asked: What would autistic children like to use VR in schools for? Here they were asked to select as many options as they wanted from a list describing ways VR might be used. Only data from the autistic children are included in this analysis. This list included all of the following options: (1) develop social skills; (2) prepare for things that scare me in the real world; (3) go to places that I'm unsure of in real life; (4) meet people / make friends; (5) it relaxes me and I feel calm; (6) I can do things on my terms, in my time; (7) I could develop learning opportunities for school in VR; (8) I could go to places virtually and see what the world looks like when we are learning about it in school. Responses were collated across these eight options from each of the participants. Apart from three participants, all (n=31) selected at least one option. Figure 6 highlights the responses to the final question on the questionnaire.

*** INSERT FIGURE 6 ABOUT HERE ***

Figure 6 highlights a clear preference from the users to their desires and potential for user HMDs and VR. Using it as a form of socialising (“making friends” or “social skills development”) appeared to be low on the participants’ agenda. Across both questions a total of 21 responses were recorded (11 and 10 respectively) for each). Being able to “do things in their own time” also appeared to be less attractive (15). However, when asked about using VR to “prepare for things that scare me in the real world” along with “go places that I’m unsure of in real life” responses jumped (almost doubled) to 21 and 22, respectively. “Developing learning opportunities at school” (20) and “going places virtually and see what the world looks

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like for learning in school” (18) both yield positive responses. Finally, when asked if VR could be used to “relaxes me and I feel calm” 29 children reported this could be a possible affordance/use of VR HMDs.

Discussion

The data reported above offers several important and novel insights to the experience of autistic- children in both mainstream and SEN settings using VR and HMDs. The need for this work is underlined by a lack of available studies and data pertaining to experience of autistic groups using VR HMDs. This view is supported by a review of literature from 1996-2017 undertaken by Fernández-Herrero et al. [9] who suggest that on the one hand, we have seen *“an increasing interest in the topic of virtual reality as an educational tool for High Functioning ASD children since 2010”* (p. 75), but on the other hand: *“the scientific production in this field is rather small considering its relatively wide trajectory, mostly concentrated between 2010 and 2017”* (p 75).

The data presented in the current study highlights a positive response towards HMD use with 6-16-year olds on the autism spectrum. A level of confidence, willingness and enjoyment using HMDs was prevalent, with all children happy to experience VR using a HMD. We suggest this is an important finding due to a lack of studies that report levels of enjoyment, use and application of VR HMDs with younger autistic populations [9]. However, we suggest that as the field grows and develops, providing data related to health and safety issues (including negative effects) needs to remain central to all research; because in doing so there will be greater uptake and interest. This is especially important if VR HMDs can in fact

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provide a safe, ecologically valid, and supportive environment for autistic users to engage with a range of experiences.

We suggest these results are important findings, as previous research examining negative effects (in particular motion sickness) have reported less favourable results. For example, Munafo et al. [10, p. 894) found that “*after playing the game for a maximum of 15 min, motion sickness was reported by 22% of [their] participants*”. Twenty-two percent in this context refers to n=8 (out of n=36 men and women). This is a finding supported by other studies (i.e. [11] and [12]), and an area that Jensen and Konradsen [2] refer to as: “*barriers to the use*” in educational contexts. Finally, Bailey and Bailenson, suggest: “*there are still many unanswered questions about immersive VR’s influence on children’s development*” [13, p.113), pointing towards the need for more considered studies assessing the potential (for positive and /or negative connotations) of VR HMDs used by all children, including those who are autistic. Finally, we suggest that effects related to motion sickness are in many ways software and hardware dependent and so this aspect needs a further consideration; leading to more nuanced investigations exploring this.

This study sought to address the limitations in literature related to virtual reality and autistic children; exploring their views, experiences and suggestions for future educational possibilities of HMDs. In doing so, it was important to consider a range of devices from low- to high- technology options. Addressing this initial question, we found that the most expensive and highest-specified-technology option was reported as the most preferred (as might be expected due to the interactive nature of the higher-end-VR HMD). Notwithstanding, and taken with the finding that the ClassVR HMD

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was reported as the least preferential technology starts to open some interesting opinions about the most suitable, relevant and helpful format used by autistic children. This coupled with the finding that teachers suggested the HTC device had the greatest potential for their children, further reinforces the users' preferences. This finding supports work reported in other studies in terms of interaction and presence (i.e. [14]) thus supporting to the preference for the users in the current study; in other words it's not too surprising that a more interactive and immersive device yielded a more positive response. However, this sentiment and feedback provides a different view to recent research in fields of education that identified: "*current HMDs are primarily entertainment devices [...] not designed for classroom use and require a level of technical skills that is a challenge to many instructors*" [2, p. 1525]. They go on to suggest a "*bring-your-own-device (BYOD) philosophy*" (p. 1525) but note this would be limited to those who can bring / have a device. So, the finding that higher-end, more expensive and technically difficult to use HMDs are preferred in our study could need further investigation in relation to use in a classroom by teachers and children. Therefore, more work and insights are needed in a classroom context; it might not be as simple or easy to provide the most preferable (and thus immersive) HMD, but that some compromise will likely need to be considered.

By considering data from the questionnaire and three categories: namely, enjoyment/usefulness (C1), physical experience (wearing the HMD) (C2), and would children use the technology again or recommend it to others (C3), we found that there was high agreement across all three categories indicating that the autistic children rated the HMD, and VR experience therein, positively. Most interesting was the finding that children in SEN schools reported higher scores across all categories

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compared to the mainstream settings; which requires further investigation to establish the reasons for this. The finding that wearing HMDs, in all their forms, was not reported as problematic helps to further support the positive nature of this technology; as reported by the users. This is similar to the findings of [7] who conclude that older autistic people (17-53 years old in their case) reported few negative effects associated with HMD use. This implies, and starts to develop an evidence-base, to suggest that VR HMDs are not a barrier for implementing virtual scenarios to support the learning of autistic- children.

Limitations

Despite several interesting and positive findings, there are some limitations and caveats to our research and findings. Firstly, we did not utilise all the functionalities of each head-mounted display. This means that future work might consider the full range of HMD functionalities and seek to experiment with the full potential each device offers. Future work could be extended to consider a more complete range of device functionality. Secondly, we worked with a small and specific group of children and only collected/reported their diagnosis of autism (along with age and gender). Further data from participants might have helped in supporting suggestions as to what device and interface suited specific children. Here we refer to the context of, diagnosis, cognitive ability and any associated co-morbidity. The field of autism and technology lacks clear guidance for what types of devices are suitable for what types of autistic users and so providing further details of children's characteristics would have been helpful in data analysis; and therefore, conclusions related to this area. This limitation also leads to us recognising that the findings reported here are

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only contextualised with the children and the schools we worked with (via a convenience sample).

Additionally, we recognise that our study used a range of devices (very diverse devices) and as such difference in preference and experience could accordingly be very different. This, in one sense, might skew our data towards devices that are more interactive (i.e. HTC Vive) compared to VR HMDs with limited input. This could have been further impacted by the order of presentation of the devices. However, this might also suggest that interactive devices are more suitable and preferable for this population as we continue to investigate this field in the early stages of development. This is also the case for the software we exposed the users to; this was diverse. Future work might consider more comparable software across devices. Linked to the differentiation of devices and software, we also acknowledge the diverse age range we worked with (i.e. 6-16 years old) and that they might have had a range of needs and preferences. As such, future work might consider a more targeted age range and also work with autistic children with similar needs and preferences.

Conclusion

This study and the data reported shed some important light of the perspectives and views of autistic children. In this context, we have better located the types of HMDs technologies that might be most successful in schools for autistic- children. We suggest that based on the feedback children that low-tech options such as cardboard HMDs coupled with a smartphone could be an appropriate first-step into using VR to transport children to various environments to augment their learning. In addition, the finding that VR HMDs might be most usefully received as a form of meditation, we

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also suggest careful thought about using VR in schools for this might provide access to a quick and easy methods to help reduce stress and increase calming feelings for autistic- children. This of course needs validating, but the feedback we received in our project seems to suggest that VR could work well in this domain and support the emotional regulation of children and young people on the autism spectrum.

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