

Brief Report: A Pilot Study of the Use of a Virtual Reality Headset in Autism Populations

Nigel Newbutt¹ · Connie Sung² · Hung-Jen Kuo² · Michael J. Leahy² · Chien-Chun Lin² · Boyang Tong²

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Abstract The application of virtual reality technologies (VRTs) for users with autism spectrum disorder (ASD) has been studied for decades. However, a gap remains in our understanding surrounding VRT head-mounted displays (HMDs). As newly designed HMDs have become commercially available (in this study the Oculus Rift™) the need to investigate newer devices is immediate. This study explored willingness, acceptance, sense of presence and immersion of ASD participants. Results revealed that all 29 participants (mean age = 32; 33 % with IQ < 70) were willing to wear the HMD. The majority of the participants reported an enjoyable experience, high levels of ‘presence’, and were likely to use HMDs again. IQ was found to be independent of the willingness to use HMDs and related VRT immersion experience.

Keywords Autism spectrum disorder · Virtual reality technology · Head-mounted display · Oculus Rift™

Introduction

The role of virtual reality technologies (VRT) represents a growing area of research within the autism field for over two decades. The term, VRT, remains fairly broad and includes VR head-mounted displays (VR-HMD; Strickland

et al. 1996), virtual environment simulations (VES; Mitchell et al. 2007; Parsons et al. 2004, 2005), collaborative virtual environments (CVE; Fabri et al. 2004), immersive virtual environments (IVE; Wallace et al. 2010), and virtual worlds (VW; Kandalaf et al. 2013; Newbutt 2013; Stendal and Balandin 2015). All of these technologies involve 3D immersive graphics, many involving avatars (representations of oneself), independent controls, and/or communication input/output.

Virtual reality technologies represent a simulation of real world training environments based on computer graphics. These can be useful as they allow instructors, therapists and service providers to offer a safe, repeatable and diversifiable environmental platform during treatment which can benefit the learning of individuals with ASD (i.e., Georgescu et al. 2014; Kandalaf et al. 2013; Newbutt 2013; Parsons et al. 2004). This emerging framework focuses on remediating the underlying deficits and maximizing the potential of an individual’s ability to develop critical skills associated with independent living and employment for transition youth and adult populations.

Most current VR environments are primarily visual experiences, using special stereoscopic displays. A variety of display devices (e.g., Oculus Rift™) offer potentially differing degrees of immersion and interactivity (Starnier 2015). Previous research and development of VRT systems have been successful at promoting specific behaviors of individuals with ASD such as following directions, crossing the street, finding a seat on the bus, ordering coffee in a café, and exiting a building during a fire alarm (see Parsons and Cobb 2011 for a review). Overall, VR systems provide the instructor/researcher with a balance between flexibility and control, as well as allowing repetitive exercises to be presented in a motivating, engaging, and naturally reinforcing way (Saiano et al. 2015; Wilson and Soranzo 2015), thus

✉ Nigel Newbutt
nigel.newbutt@uwe.ac.uk

¹ Department of Arts and Cultural Industries, University of the West of England, Bristol, UK

² Department of Counseling, Educational Psychology and Special Education, Michigan State University, East Lansing, MI, USA

helping to provide an individual with ASD a safe space to test social situations and respond to these situations.

In summary, through two decades of research examining the role of VRTs for people with ASD, and the promising results of various studies (Cobb 2007; Maskey et al. 2014; Parsons and Cobb 2011; Parsons et al. 2005, 2006; Smith et al. 2014, 2015, Strickland et al. 1996, 2007, 2013), we are well placed to continue investigating further these tools and technologies for this specific user-group. This is especially the case as new technology has since evolved considerably and the nature of VR experiences change. There are no published studies to date concerning newer, smaller, lighter, and easier to wear HMDs and the impact on users with ASD. As a result of this gap in literature, there is a need to revisit the similar questions raised by Strickland et al. (1996) surrounding acceptability and willingness to engage with HMDs. We speculate that assessing the acceptance and immersive experience in this new form of VRT (with users on the autism spectrum) is especially important to help our understanding of the interpretation of VR spaces in addition to any level of discomfort felt while using HMDs. The Oculus Rift™, which was first introduced in 2012, along with many other HMDs have helped to improve the accessibility of VR headsets in both the size of headset (smaller and considerably more wearable than earlier iterations) and the cost (more affordable to many consumers; Starner 2015). As a result of these accessible and wearable technologies, we argue that the evaluation of acceptance, presence and possible negative effects of HMD VRTs is worthy of review. Without asking some of these fundamental questions, the field remains unsure about the sensory experiences of people with ASD and possible negative effects experienced in a VR environment (i.e., discomfort, cybersickness). It is important to note that the version of hardware used in the current study includes position tracking, which “helps with reducing the dizziness, the brain does not get confused by the missing degree of motion” (Starner 2015, p. 177). While technology can help overcome some experiences of dizziness and nausea, research tends to suggest that “cybersickness represents an ongoing obstacle for the widespread development and acceptance of VR especially for everyday use” (Davis et al. 2015, p. 11). Finally, Steinicke and Bruder (2014) have found (albeit through substantial exposure) HMDs can have a negative effect. Taken as a whole, there are several concerns related to the possibility of discomfort when/after using HMD VRTs.

Therefore, we propose a study examining the acceptance of using these devices. The specific research aims of the current study are to:

1. Investigate the willingness and acceptance of VR-HMD (i.e., Oculus Rift™) among people with ASD and whether they might be able to use it in a meaningful way; and
2. Present a series of 3D immersive experiences within the VRT to measure the immersion and other experiences of a VR-HMD by users with ASD.

Method

Participants

A total of 30 individuals with ASD were initially identified and contacted with 29 of them expressing an interest and willingness to participate in the study. Mean age of participants was 32.02 years ($SD = 9.88$) and the majority of them were male ($n = 22$). Every participant had a previous clinical diagnosis of ASD with about half of them ($n = 11$) having a co-occurring intellectual disability (IQ score < 70). Participants' IQ score ranged from 45 to 138 ($M = 83.58$; $SD = 23.69$). Table 1 provides a summary of participants' demographics.

Procedure

Participants were recruited using convenient sampling through a private non-profit community rehabilitation organization in a Midwestern state in the U.S. Support staff of the potential participants were invited to an initial research meeting in which the goals and procedures of the study were introduced and explained. These supporting staff were then encouraged to disseminate a recruitment flyer and a video showing research procedures to their clients with ASD that fit the study requirement. After participants signed up for the study, the voluntary nature and purpose of the study were explained to each participant followed by informed consent. For those who were under guardianship, the research personnel first explained the study to both the participant and their parent/guardian, and assent and consent were obtained from each of them separately and independently.

To begin, a basic demographic questionnaire and the Wechsler Abbreviated Scale of Intelligence (WASI; Wechsler 1999) were administered to each participant. The participant then proceeded to the Phase I experimental session and used a HMD VRT (see VRT section below) for approximately 10 min to navigate through three short and simple VR scenarios. At the end of the session (Phase I), each participant was asked if he/she would like to return for Phase II of the study, which involved longer and more intense VR experiences. Out of the 29 participants, 23 of them were willing to return. Reasons for why not returning for Phase II were solicited from the six participants that

Table 1 Demographic characteristic of the participants who took part in Phase I and II of the study

	ASD group in Phase I (N = 29)	ASD group in Phase II (N = 11)
Demographics		
Mean age (SD)	32.02 (9.88)	29.77 (8.66)
Age range	17–53	19–43
Gender (% male)	76 % (n = 22)	91 % (n = 10)
Race		
Caucasian	83 % (n = 24)	73 % (n = 8)
African American	10 % (n = 3)	18 % (n = 2)
Others	7 % (n = 2)	9 % (n = 1)
Vocational history		
Full-time employed	34 % (n = 10)	27 % (n = 3)
Part-time employed	66 % (n = 19)	73 % (n = 8)
Formal ASD diagnosis		
Autistic disorder (% yes)	55 % (n = 16)	64 % (n = 7)
Asperger's (% yes)	34 % (n = 10)	18 % (n = 2)
PDD-NOS (% yes)	10 % (n = 3)	18 % (n = 2)
Intellectual ability		
IQ score mean (SD)	83.58 (23.69)	86.63 (30.70)
IQ score ≤ 69	34 % (n = 10)	18 % (n = 2)
IQ score ≥ 70	66 % (n = 19)	82 % (n = 9)
IQ (lowest/highest)	45/138	53/138
Comorbidity ^a (% yes)	59 % (n = 17)	64 % (n = 7)

^a Comorbidity included: epilepsy, attention deficit hyperactivity disorder (ADHD), anxiety, depression, Down syndrome, Fragile X syndrome, and hearing impairment

included time constraints (N = 2) and negative effects experienced such as dizziness and tiredness (N = 4). Eleven of those 23 participants were then randomly selected to return and participate in Phase II experimental session, which consisted of two longer and more intense VR scenarios, lasted for about 25 min.

After their VR experience in Phase II, each participant completed an immersion experience questionnaire. For participants who had low cognitive and/or reading level, all self-report measures were administered with assistance (e.g., reading items in verbatim, providing explanation and/or visual rating scale) provided to them. Each individual session (across both Phases) was captured using a video-recorder and a digital camera. In addition, an observer (i.e., a trained research assistant) took qualitative notes on participants' verbal and non-verbal behavioral responses to the VR experiences during each session.

Ethical Consideration

Ethical considerations and safety concerns of the participants were both paramount to this study. The research team was conscious of possible effects from the VR-HMD (see Sharples et al. 2008 for an overview) especially as no formal or published study had previously used this

technology or equipment with the ASD population. Prior to this study, Institutional Review Board (IRB) approval was obtained from the researchers' affiliated institution. During the participant recruitment process, support staff of the community rehabilitation organization were engaged in disseminating study information to potential participants, including a recruitment flyer and a short video showing the technology and explaining the process. This helped to fully communicate the details of the study and prepare participants to use the technology properly, and in some cases to answer questions and/or concerns participants had. During the actual experiment, the researchers adopted a practice allowing the participants to try on the VR-HMD in stages with regular check-in and monitoring their reactions, which strategically and safely guided them into the immersive and intensive interactive VR experiences.

Virtual Reality Technology: Hardware and Software

The hardware used in this study was minimal and portable, which included: (1) an Oculus Rift™ head-mounted display; (2) headphones; (3) an Xbox 360™ controller; and (4) a laptop computer. Figure 1 illustrates the technology used in the study.



Fig. 1 Equipment used in the current study. 1 PC laptop, 2 headphones, 3 game-pad input controller, 4 head-mounted display; Oculus Rift™

Studies (e.g., Newbutt 2013; Cobb et al. 2014) have emphasized the importance of using technologies within naturalistic settings, helping to embed them in the most meaningful way. As such, the size, portability and flexibility of the hardware were important since ultimately the technology might be used to enable more in-context work in the future. Most importantly, the positive nature of VRT for people with ASD will be better realized if they are placed in settings where they stand to be of the most benefit (e.g., school, home and/or work settings). The study was undertaken in a contextual setting (see Fig. 2).

Due to the hardware being relatively new (the developers' version of Oculus Rift™ was released mid-2014), the option of VR scenarios was somewhat limited. Three simple and short VR scenarios were chosen for Phase I whereas two longer and more intense VR scenarios were selected for Phase II. Both utilized a commercially available software "off the shelf" which were identified to slowly increase the intensity of the VR experiences and help engage participants in a gradual and safe way. Table 2 highlights the Phases of study and associated interfaces/scenarios provided. Figures 3 and 4 provide an illustration of visual experiences during Phase I and II, respectively.

Measures

Demographic Questionnaire

Demographic information were collected from each participant and the number of successfully completed VR scenarios by the participant was recorded. After 1 week,



Fig. 2 Illustration of the room we used at the community rehabilitation organization, the layout, environment and set up. Right participants, left researcher(s)

post-experimental session, a follow-up survey was used to gather information regarding longer-term effects and participants were asked to rate their enjoyment and likelihood of using a VR-HMD again on a 5-point Likert scale.

Immersion Experience

The Independent Television Commission-Sense of Presence Inventory (ITC-SoPI; Lessiter et al. 2001) was used to measure the subjective effects experienced by an individual within the virtual environment (i.e., presence of 'felt'). Similar to previous studies in the field of autism (e.g., Wallace et al. 2010; Wallace et al. 2016), the ITC-SoPI was selected for the current study due to its encompassing nature. This measure was found to be valid and appropriate in assessing subjective immersion experience and negative effects (nausea and dizziness) post-VRT usage with acceptable psychometric properties (Gorini and Riva 2014; Villani et al. 2012). The ITC-SoPI consisted of 38 items and four domains (factors) which contain key aspects related to a VRT experience: (1) spatial presence (2) engagement, (3) ecological validity, and (4) negative effects. Each item in the ITC-SoPI was rated by the participants on a 5-point Likert scale (1 = *Strongly disagree*

Table 2 Overview of the Phase of study (I or II) and stimulus provided at each stage and Phase

Phase of study and type of VR experience	Description of activity and goal(s)
Phase I: a virtual cinema (watching a film as if they were in the front row of a cinema)	The participants could choose a variety of films to watch. Goal(s) of this scenario was to simply introduce the participant to the technology, provide them with some control of the setting so as to ease them into the scenes and environment
Phase I: a virtual café (sitting in a café opposite another person in a seat)	The virtual character would maintain eye contact with the participants if they looked at the character. Goal(s) of this scenario was to immerse the participant in a simulated social setting
Phase I: a virtual safari (driving a Jeep around the Africa Savannah)	The participants were prompted to use a controller to maneuver the car. The participants could look for animals as part of their 'journey'. Goal(s) of this scenario was for the participant to engage with a moving and highly stimulating scene in addition to helping them to realize the full potential of the technology
Phase II: an Apollo 11 mission	The participants were taken through a historical tour related to Apollo 11 and experienced boarding the spacecraft, taking off, and entering zero-gravity. Goal(s) of this scenario was to immerse the participant into an engaging and highly involved (learning) experience for a substantial period of time
Phase II: a Tuscan house	The participants were taken to a Tuscan house in extensive grounds where they could see views across a lake and towards hills beyond. Goal(s) of this scenario was for the participant to experience a highly realistic scene with an added ability to navigate to become fully immersed



Fig. 3 Examples of Phase I interface as experienced in the HMD. *Left* virtual café (image used with copyright permission from Tore Knabe, www.tore-knabe.com), *right* virtual safari (image used with permission from Gert-Jan Verburg, www.vergevr.com)

to 5 = *Strongly agree*). Factor scores were computed as per the ITC-SoPI scoring criteria. Specifically, for subscale 1, 2 and 3, higher scores indicate greater sense of presence and immersion, and for subscale 4, a lower score reflects less negative effects. The Cronbach's α of the current study was reported as between 0.65 and 0.92 with factor 2 (engagement) being the lowest.

Behavioral Observation

Each participant's verbal and nonverbal behavioral reactions to the use of VR-HMD were recorded and observed by a trained research assistant with qualitative notes taken

during each session. However, only brief qualitative information on behavioral observation was reported in this article, as they are considered beyond the scope of the research questions set out in the current study.

Data Analysis

Due to small and unbalanced sample size ($N = 11$) of both groups, Chi square test and Mann-Whitney U test were used to examine, respectively, the differences in acceptance of (willingness to use) HMD and perceived immersion experience between the ASD participants with and without intellectual disability.

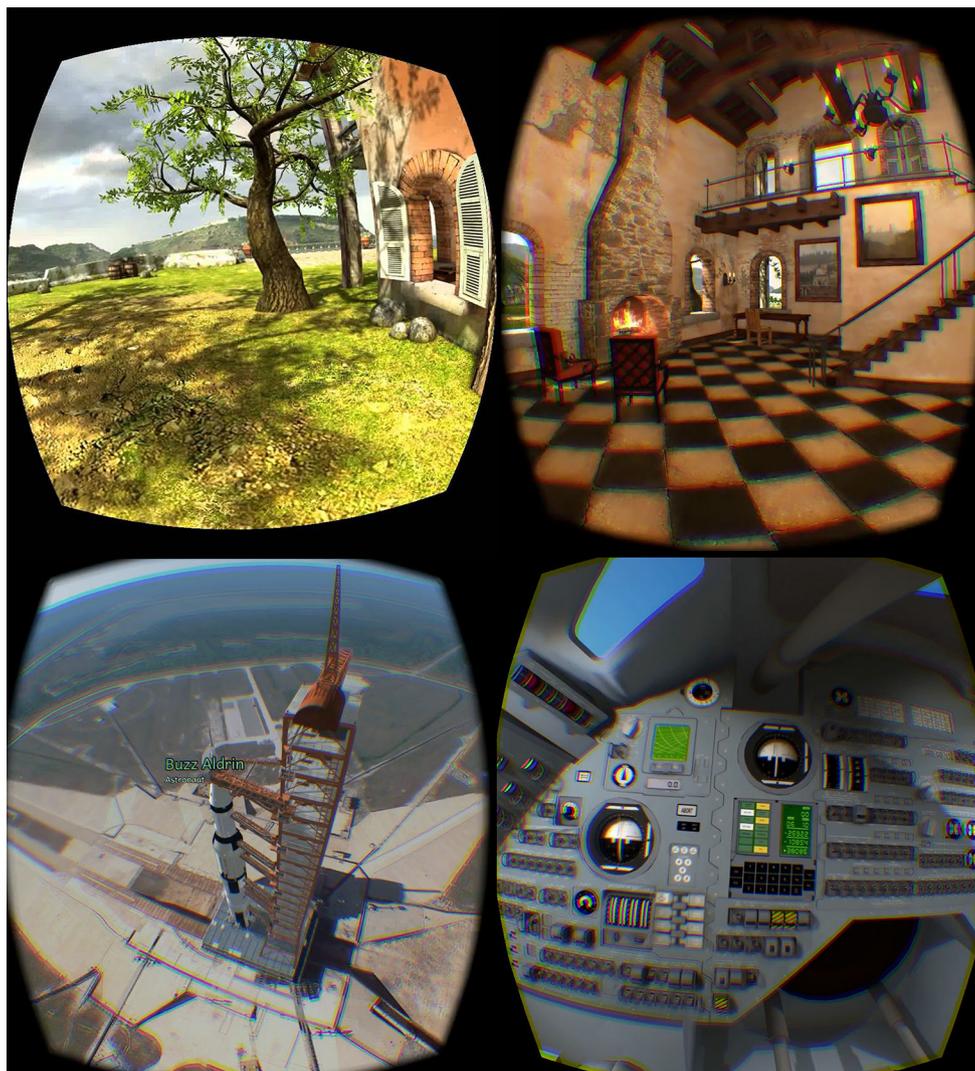


Fig. 4 Examples of Phase II interface as experienced in the HMD. *Top* Tuscany Village outside and inside locations, *bottom* Apollo 11 mission outside rocket and inside (image used with permission from David Whelan, www.immersivevreducation.com)

Results

Willingness and Acceptance of VR-HMD

In Phase I, all 29 participants were willing to wear the VR-HMD and experienced at least two of the three pre-selected VR scenarios (scenarios 1 and 2). Twenty-five of them (86 %) completed all three scenarios while the remaining four participants requested to discontinue using the HMD after the second VR experience (i.e., virtual café). During phase II, all 11 participants (100 %) completed the two pre-selected scenarios. Across Phase I and II, every participant in this study was willing to wear the HMD and indicated a level of acceptance in the context it was set (see Table 3). In addition, Table 4 highlights the successful completions of all three tasks during Phase I

classified into two IQ ranges of the participants (≤ 69 and ≥ 70) to help better understand association between the VR-HMD experience and IQ level. Results revealed that there is no significant difference ($p < 0.001$) in acceptance of HMD and emersion experience between the two groups of ASD participants (with and without intellectual disability) indicating participants' IQ is independent to their willingness to use HMD and related VRT immersion experience. Analyzing the demographic questionnaire and the *level of enjoyment of the VR-HMD experience*, all participants reported a score of 3 (out of 5) or above, with a mean score of 4.32 ($SD = 0.69$). As for the *likelihood of using VR-HMD again*, majority of the participants (with the exception of two participants) reported a score of 3 (out of 5) or above, with a mean score of 3.92 ($SD = 1.98$).

Table 3 Percentages (%) and number (n) of participants who were willing to wear the HMD and complete various VR experiences during Phases I and II of the study

Phase I	N = 29
Willing to wear the HMD (% yes)	100 % (n = 29)
Completed first experience (% yes)	100 % (n = 29)
Completed second experience (% yes)	100 % (n = 29)
Completed final experience (% yes)	95 % (n = 25)
Participants willing to return for Phase II of the study (% yes)	79 % (n = 23)
Phase II	N = 11
Willing to wear the HMD (% yes)	100 (n = 11)
Completed all two experiences (% yes)	100 (n = 11)

Table 4 Percentages (%) and number (n) of participants classified by IQ scores of ≤ 69 and ≥ 70 who completed all three VE experiences (cinema, café and safari) during Phase I and those who completed all

two intense VE experiences (Apollo 11 mission and Tuscan house) during Phase II of the study

	IQ score ≤ 69 (n = 10)	IQ score ≥ 70 (n = 19)
Phase I		
Percentage (number) of participants completing Phase I (all three VEs)	80 % (n = 8)	89 % (n = 17)
Percentage (number) of participants indicating a willingness to return for Phase II	80 % (n = 8)	79 % (n = 15)
Phase II		
Percentage (number) of participants completing Phase II (all two VEs)	100 % (n = 3)	100 % (n = 8)

Qualitative findings from behavioral observations during the sessions noted that participants at times spontaneously reported their reactions to the VR environments and wearing the HMD. Some examples included: “feels good... it was okay... I can get used to it” (subject #1); “it was nice... the experience is awesome... you’re immersed to what you’re doing... enjoying it” (subject #4); and “amazing... it is so cool... I love it” (subject #7).

Despite many positive comments being reported by the participants, four of the participants did not complete all of the HMD VR scenarios and expressed the desire to discontinue due to some minor negative effects (e.g., dizziness and tiredness) experienced from the HMD. Comments from these participants included: “if you look too fast [referring to moving their head], I can see why some people don’t like that” (subject #11). Additionally, one participant reported: “the headset bugged me” (subject #5), while another indicated the scene was “a little blurry” (subject #3).

Immersion Experience and Sense of Presence

Immersion experience and sense of presence were investigated during Phase II of the study. Factors that were specifically identified in the ITC-SoPI were: spatial presence, engagement, ecological validity and negative effects.

Among the participants who participated in Phase II, spatial presence was reported above average ($M = 3.8$; $SD = 0.62$) with both engagement and ecological validity reporting high scores ($M = 4.1$; $SD = 0.57$ and $M = 4.0$; $SD = 0.33$, respectively). Finally, the factor related to negative effects was reported as low ($M = 2.0$; $SD = 0.34$). Table 5 highlights results from the ITC-SoPI in the current study.

Discussion

To better understand the potential for VRT and HMD to be used among people with ASD, this study sought to investigate their acceptance of using a VR-HMD. Our findings from behavioral observations and self-reported questionnaires revealed that people with ASD generally accepted the HMD and were willing to complete the tasks associated with VR scenarios in full. This finding is interesting for two reasons. First, there has been concerns surrounding the sensory (sensitivity) and cognitive issues which users with ASD might experience using HMDs (Wallace et al. 2010). However, very limited, if any, formal studies have reported what happens if users with ASD wear and engage with this technology. The results of this study provide some initial evidence that this particular user group reported very

Table 5 Mean (M) scores, standard deviation (SD) and internal consistency reliability (Cronbach's α) of the four ITC-SoPI factors post-VRT experiences during Phase II of the study

	All Participants (n = 11)	Participants with IQ score \leq 69 only (n = 3)	Participants with IQ score \geq 70 only (n = 8)	Cronbach's α
	<i>M</i> (<i>SD</i>)	<i>M</i> (<i>SD</i>)	<i>M</i> (<i>SD</i>)	
Spatial Presence ^a	3.76 (0.72)	4.30 (0.72)	3.56 (0.65)	0.88
Engagement ^b	4.15 (0.43)	4.31 (0.61)	4.09 (0.38)	0.65
Ecological Validity ^c	4.00 (0.86)	4.40 (0.72)	3.85 (0.90)	0.84
Negative Effects ^d	2.03 (0.95)	2.11 (0.19)	2.00 (1.13)	0.92

A score of 1 = strongly disagree; 2 = disagree; 3 = neither agree nor disagree; 4 = agree; 5 = strongly agree

^a Feeling as thought being present in the environment

^b Feeling involved in the environment and an intense experience

^c Natural and believable experience/environment

^d Negative effects refer to dizziness, nauseous, tiredness, headache, eyestrain

minimal negative effects wearing a HMD or experiencing VR scenarios. Second, our findings will potentially enable other practitioners and researchers to continue developing evidence-based interventions using this technology as the data tend to support acceptance and willingness to use and a positive experience. If used appropriately and in-context, we suggest that with further research and substantial evidence, the realism experienced through using HMDs could further help the generalizability from the virtual to real-world contexts for this population, thus making VRT experiences valuable. We also argue that the generalization from virtual to real-world has to be one of the key objectives for future research—and also that the heightened sense of presence and ecological validity that HMDs can offer warrants further investigation (Cheng et al. 2015). Finally, we drew attention to the participants who decided *not* to complete all VR experiences, with specific regard to the IQ average presented therein (see Table 4). Participants of various IQ showed similar willingness to complete all the VR scenarios and/or return for more intense VR experiences. In other words, the results indicated that participants' IQ is independent to their willingness to use HMD and their related VRT immersion experience. This finding provides some initial insight, despite the small sample size, that VR as a means of intervention could be considered and applied to individuals on the autism spectrum with a full IQ range. That being said, more research is needed to draw such a conclusion.

In addition to the positive findings related to the acceptance and experience of wearing and using VR-HMDs, our participants with ASD reported higher spatial presence, engagement and ecological validity within the VR environment and lower levels of negative effects. Results revealed that users with ASD appeared not to experience sensory issues. Such findings concurred and further supported the line enquiry undertaken by Cheng

et al. (2015) and Wallace et al. (2010), although using a different HMD technology. Furthermore, the heightened sense of presence and ecological validity suggested that the experiences viewed through the HMD (compared to conventional screen-based displays) were seen as 'real' and could happen in real-life. This is an important indicator if we are to continue investigating the use of VRTs for ASD populations, with the hope to foster real-life skills development and the ultimate goal of skills generalization. Despite many positive experiences being reported, a few participants wanted to discontinue the HMD VR experience. Therefore, taking ethical considerations and applying appropriate ethical practices remain a critical concern for this type of work, in addition to understanding the limitations of HMD technology for some of these users. Overall, there is a positive picture immersing regarding the use of HMDs and VRTs in ASD populations. Further research is warranted which should better target and triangulate views and experiences to ratify these claims.

Limitations

While this study reveals some positive and interesting findings, there are also several limitations. First, given the exploratory nature, only individuals with ASD from a community rehabilitation organization were included in this study. Hence, results should be interpreted with caution due to the potential selection bias and limited generalizability of the findings. More substantial work with specific and targeted outcomes must be carried out before the role of HMDs can be realized and generalizability claims can be substantiated. Second, the use of self-report questionnaires among people with ASD/ID makes the results vulnerable to error and bias. Objective measurement on VR-related experiences could be further explored while

comparing results to typically-developing users. Third, the confirmation of an ASD diagnosis for the participants is also a limitation. While each participant had a medical record of clinical diagnosis, further validation is something future work should consider. Another limitation is related to the length of the study and the amount of HMD-VR exposure (or dosage) the participants received. This was in part due to ethical concerns, and as the first of this kind of study, we were careful not to expose the participants to the VR experience for long periods. However, longer periods of exposure (or dosage) might yield different results (Kandalaf et al. 2013; Ke and Im 2013; Wilson and Soranzo 2015). Such findings are preliminary until further evidence in this field is targeted. We remain clear that while this study provided some of the very first and preliminary data using VR-HMD with a wide-ranging ASD group, this type of study requires further validation, comparison to a typically-developing group, and inclusion of larger samples for various exposure/dosage) to allow researchers to better understand the potential of VRT.

Implications and Future work

By understanding the willingness to use HMDs, practitioners and researchers should be better placed to embark on an agenda that considers the potential of this new and evolving technology. By applying similar affordances of more traditional and well-researched screen-based VRTs, HMD VRTs could provide greater immersion that helps in developing more cost-effective interventions, support and develop confidence for users with an ASD. Most importantly, greater immersion could lead to better generalizations of learning to the real-world; and that is where this line of enquiry stands to benefit most. It has been shown that having an increased sense of presence in a virtual environment can help promote learning (Wallace et al. 2010), in addition to feeling a connection and engagement with the environment (Yee et al. 2007). Therefore, future work should: (1) consider larger samples; (2) maintain the in-context setting; (3) develop specific and bespoke software; and (4) consider both qualitative and quantitative data to ensure a rich dataset for interpretation.

Future work considering VRTs and users with an ASD should consider carefully the key affordances of this technology and seek ways to develop material to target interventions and learning opportunities. Potential applications include promoting social skills (Parsons et al. 2006; Parsons and Cobb 2011), employability (Kandalaf et al. 2013) and independent living contexts. While there has been some progress in testing the relevance and applicability of VRT for individuals with ASD/ID in laboratory settings, there remains a significant challenge in developing

robust and usable technologies that can really make a difference in real world natural contexts (Parsons and Cobb 2014; Newbutt 2013). The current study is one of the studies to have worked with a group of ASD participants, and with their caregivers (both parents and support workers), in a community-based setting. Future work is needed to maximize possible uptake and use of technology for users with an ASD in contextually appropriate and beneficial settings.

Conclusions

This was an exploratory and preliminary study to better understand how people with ASD experience using HMDs and VEs therein. The results of this study suggested that the majority of the participants with ASD generally accepted and were willing to use this form of technology. These positive findings shed light on future research in trying to establish an evidence-based intervention by using HMD VRTs in contexts that stand to support this user group (and/or other disability groups). While adults being the target population of the current study, the potential for this line of enquiry and future work should consider younger user groups with a view to validating the acceptance and experiences therein.

Acknowledgments The authors wish to thank the staff of Peckham Inc. and their valuable time in working with the research team on this project. Their expertise, assistance and inputs were invaluable. We would also like to acknowledge the participants who were willing to try this technology and provide feedback; their time and inputs are truly appreciated. This study was funded by the Engineering and Physical Science Research Council (EPSRC) and a Digital Economy Sustainable Society Network+. Grant Number (EP/K003593/1).

Author Contributions NN conceived of the study, participated in its design, interpreted the data, and drafted and critically revised the manuscript. CS and HK were instrumental in the design and acquisition of the data, analyzed and interpreted the data, and critically revised the manuscript. In addition, CS, HK and MJL worked closely with the community rehabilitation organization and key stakeholders therein. MJL participated in the acquisition of the data and critically revised the manuscript. CL and BT participated in the acquisition of the data, assisted in analyzing and interpreting the data, and readings/edits to the manuscript. All authors read and approved the final manuscript.

Compliance with Ethical Standards

Conflict of interest All authors have no conflict of interest.

Ethical Standard All procedures performed in this study involving human participants were in accordance with the ethical standards of the Institutional Research Committee.

Informed Consent Informed consent was obtained from all individual participants included in the study.

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