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Sense of presence and atypical social judgments in immersive virtual environments

Responses of adolescents with Autism Spectrum Disorders

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ABSTRACT Immersive virtual environments (IVEs) are potentially powerful educational resources but their application for children with Autism Spectrum Disorder (ASD) is under researched. This study aimed to answer two research questions: (1) Do children with ASD experience IVEs in different ways to typically developing children given their cognitive, perceptual and sensory differences? and (2) Can an IVE accurately simulate ecologically valid social situations? Ten children with ASD and 14 typically developing (TD) adolescents all aged 12–16 years experienced three different IVEs. They completed self-report questionnaires on their sense of 'presence' in the IVEs and rated 'social attractiveness' of a virtual character in socially desirable and undesirable scenarios. The children with ASD reported similar levels of presence to their TD peers and no negative sensory experiences. Although TD adolescents rated the socially desirable character as more socially attractive than the undesirable character, adolescents with ASD rated the two characters as equally socially attractive. These findings suggest that children with ASD do not experience IVEs in different ways to their TD counterparts and that the IVEs are realistic enough to simulate authentic social situations. This study paints a very encouraging picture for the potential uses of IVEs in assessing and educating individuals with ASD.

KEYWORDS
Autism Spectrum Disorder; virtual reality technology

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The potential benefits of virtual reality (VR) technology for supporting the learning of children with Autism Spectrum Disorder (ASD) are increasingly being recognised in the research literature (e.g., Parsons and Mitchell, 2002; Goodwin, 2008; Schmidt and Schmidt, 2008). Virtual environments (VEs) are 3-D computerised representations of 'real world' or imaginary scenarios and can be designed to allow the user the freedom to navigate through an environment (e.g., a house or a street) and interact with objects and people. VEs have a number of features that offer unique possibilities for teaching individuals with ASD, including the facility to programme scenes in such a way that potentially confusing or threatening inputs of real world interactions (such as noise levels, number of people present) can be controlled; and the capacity to practice behaviours and responses in a context that shares some similarities with the real world, thereby offering greater potential for generalisation of learning.

The responses of children with autism in VEs have been explored in a variety of social domains including understanding facial expressions (e.g., Fabri et al., 2007) and social conventions (Parsons et al., 2004, 2005; Mitchell et al., 2007). In addition, authors have investigated the usefulness of VEs for directly tackling real-world hazards such as crossing the road (Josman et al., 2008) and evacuating a building in response to a fire alarm (Strickland et al., 2007) or tornado warning (Self et al., 2007). In all cases, children with autism have learned new information from these 3-D representations and have responded in ways that suggest they understand that the VE can offer useful information about the real world. In addition, earlier studies demonstrated that children with ASD were highly motivated by computer technologies, suggesting this could be a powerful educational tool (e.g., Chen and Bernard-Opitz, 1993; Moore and Calvert, 2000). Viewed in the context of the general ubiquity of technology in classrooms, and the popularity of interactive computer games and online virtual worlds (e.g., Second Life), such findings point towards the important role that VE technologies could play in our future classrooms.

Despite these few promising results and the clear relevance of technologies in the education of children with ASD, there remain many unanswered questions regarding the usefulness as well as the limitations of VR technology as an educational tool for children with autism. With regard to the latter in particular, known perceptual, cognitive and sensory tendencies in children with ASD may cast some doubt on the usefulness of VR for facilitating learning. Specifically, eye movement studies have shown that children with ASD tend to focus on (different or inappropriate) details of visual displays compared to typically developing children (e.g., Klin et al., 2002). In addition, some children with ASD are known to experience sensory difficulties or overload in response to particular stimuli (e.g., Rogers et al., 2003). These factors could render VEs as uncomfortable or unfathomable experiences for children with ASD or, at the very least, hinder their chances of interpreting the scenes in an appropriately representational way (i.e., understand that the scenes have some relevance to real-world situations).

As Rizzo et al. (2004) note, VR is a potentially powerful tool, offering significant opportunities for education and rehabilitation; with such innovative technology, however, comes ethical and methodological challenges for researchers in terms of understanding what the 'optimal use' of such systems may be (Rizzo et al., 2004, p. 194). Such challenges and responsibilities are highlighted by Blascovich et al. (2002), who argue that immersive VEs (IVEs) in particular offer a useful tool for social science more widely. IVEs 'perceptually surround the individual' such that '. . . the individual perceives himself or herself to be enveloped by, included in, and interacting with an environment that provides a continuous stream of stimuli' (p. 105). Thus, this perceptual enveloping along with 'reality rich' representations and contextual cues mean that

> we can expect immersive virtual social interactions to most closely resemble face-to-face interactions and, therefore, provide the basis for studying the effects of the actual presence of others, not to mention providing bases for studying the implied or imagined presence of others. . . . Immersive virtual environments provide . . . exceptional experimental control while maintaining a high degree of mundane realism . . . [and are therefore] a formidable tool for conducting social psychological research. (Blascovich et al., 2002, p. 111)

If, as Blascovich et al. argue, IVEs can simulate authentic 'real world' environments with a high degree of veridicality, then they also stand to tell us more about how people with autism respond to, interpret and interact with, the real world. Knowing more about this then provides a sound basis for using IVEs as educational devices that can target specific social difficulties in a safe and controlled environment.

Thus, the present study was carried out to explore how young people with ASD experience and respond to an immersive virtual environment in which highly realistic representations as well as socially themed scenarios were presented. This is, to the best of our knowledge, one of the first systematic investigations into the use of IVEs for children with autism. Early studies into the potential of VR for children with autism (Strickland, 1996, 1998; Strickland et al., 1996) included case studies of young, minimally verbal children who experienced immersive VR through head-mounted displays. However, there are significant restrictions regarding the use of these input devices, especially for children who may already experience sensory difficulties. The 'Blue Room' used in the present study is state-of-the-art technology that works by animations being projected onto the walls and ceilings of a screened space, with sophisticated software working to run these screens in synchrony to create a highly immersive and fluid virtual experience (see Figure 1). One of the chief advantages of the Blue Room (compared to other immersive VR platforms) is that there is no requirement for the user to wear any headsets or goggles to experience the perceptual immersion of the environment. This means that the user can easily walk into, around, or out of the technology space, thereby offering the potential for a more naturalistic and 'direct' experience with the displayed scenes, as well as rapid removal if there is any sign of distress. Therefore, the Blue Room offers a potentially powerful, as well as accessible and intuitive environment in which photo-realistic, 3-D moving images can be carefully controlled and responses monitored and evaluated.

There are two main (related) research questions arising from the use of the Blue Room IVE with children with ASD that we aimed to investigate in the present study:

(1) *Autism-focused question*: Do children with ASD experience IVEs in different ways compared to typically developing children given their cognitive, perceptual and sensory differences or difficulties?

Figure 1 **A participant experiencing the street environment inside the Blue Room**

(2) *Technology-focused question*: Can the Blue Room accurately simulate ecologically valid social situations?

To answer the first question, we used a 'Presence' questionnaire, which is designed to measure feelings of immersion, ecological validity and negative effects in the VE. Presence is a subjective psychological response to being within a VE – a sense of 'being there' – and has been argued to be a key moderating variable between experience and outcome in VEs developed as educational tools for children with ASD (Rizzo et al., 2004). In other words, increased feelings of presence, and having an authentic experience, are important to the likely effectiveness of a VE in promoting learning. The second question was tackled by measuring 'social attractiveness' using a questionnaire which asked participants to rate how much they enjoyed interacting in one of the scenes with a virtual character ('Danny') and whether he could be their friend. Danny's level of 'social desirability' was varied so that in one scene he behaved in a socially acceptable way whilst in a second scene he did not.

In summary then, the main objectives of the study were as follows:

(1) To assess whether children with ASD report the same sense of presence as typically developing children in IVEs; most importantly, do children with ASD find it equally naturalistic and have no negative sensory responses?
(2) To investigate whether children with ASD show atypical social judgments in immersive virtual environments compared to typically developing children.

Ethical considerations

Given the possible concerns raised by the differing cognitive, sensory and perceptual profiles of children with ASD, as well as the largely untested application of IVEs for members of this group, we were very aware of our ethical responsibilities in planning and implementing this study. In order to ensure that we were not proceeding with the development of a technology that was going to be aversive or uncomfortable for participants on the autism spectrum we adopted an inclusive design process involving teachers, parents, adults and young people with ASD as well as typically developing children. The details of this process are beyond the scope of the present article but involved some informal focus groups with these key 'stakeholders' where they were able to observe and experience the Blue Room and make design recommendations for the study.

Of particular interest during this process were, of course, the responses of the children with ASD. In all cases, they were interested in the technology and willing to explore it; their teachers who accompanied them to the sessions supported them in doing so. They also made some excellent design recommendations for the study which were taken forward in development and are described below in the IVE scenarios section. The positive responses to these informal sessions provided confidence that applying the technology would be genuinely exciting for the young people involved and would not be ethically dubious. Following this process, schools were identified for possible inclusion in the study, and informed consent from parents and assent from all the young people was obtained. All procedures and protocols for the study were submitted for ethical review to the Oxfordshire NHS REC and approved prior to the commencement of the study.

Method

Participants

Ten adolescents (9 males, 1 female) on the autism spectrum (ASD group) aged 12–16 (M = 14.0 yrs; *SD* = 1.2), and 14 typically developing (TD group) adolescents (12 males, 2 females), also aged 12–16 (M = 13.3 yrs; *SD* = 1.0), took part in the study. The participants were recruited from two special needs and two mainstream comprehensive schools in the north east of England. The Autism Diagnostic Interview – Revised (ADI-R; Lord et al., 1994) was completed via parental report for the children with ASD to confirm their clinical diagnosis. Nine of the participants scored above cut-offs on all three domains, except one participant who scored a single point below cut-off on the social domain. Participants in the ASD group had all received a previous clinical diagnosis of either autism (*n* = 5) or Asperger syndrome (*n* = 5). None of the participants were taking medication or had a history of epilepsy. All participants completed the Wechsler Abbreviated Scale of Intelligence (WASI; Wechsler, 1999) to ascertain verbal, performance and full IQ. The ASD and TD groups were comparable in terms of average age and IQ. Table 1 summarises age and IQ details for both groups.

Table 1 **Mean (*M*) scores, range and standard deviations (*SD*) on age and IQ measures for ASD and Typically Developing groups**

	ASD (n = *10)*			*Typically Developing* (n = *14)*		
	M	*Range*	SD	M	*Range*	SD
Age	14yrs	12–16yrs	1.2	13yrs 3m	12–16yrs	1.0
Verbal IQ	95.3	70–121	19.7	94.9	78–112	10.3
Performance IQ	95.5	75–120	16.5	91.2	79–115	11.0
Full IQ	95	74–124	19.8	92	82–111	9.7

IVE scenarios

Each scenario was informed by design recommendations from the focus groups and was intended to reflect a familiar context or possible social interaction. In each of the three VEs the participants were unable to control the scene (e.g., by using a joystick) or interact with objects/avatars via a touch screen but instead they watched what was presented to them on the screens and listened to the accompanying soundtrack. The scenes were presented to participants in a fixed order, as follows (and as are depicted in Figure 2a–c):

(1) *Residential street scene*: This scene provided a sense of walking along a residential pavement, next to a road which showed cars moving in opposite directions (see Figure 2a). Pedestrians walked along the pavement and participants were asked to observe what was appearing on the screens and listen to the traffic and typical street noises. The scene began at one end of a residential street, continued along the pavement passing two pedestrians and ended at a junction with a zebra crossing. The scene lasted 64 seconds in total.

(2) *School playground scene:* This was designed to replicate a school playground, which was surrounded by a school building on one side and a residential area on the other. The scene, lasting 40 seconds, navigated through the playground towards a group of children playing. The participant was greeted by a virtual school-age boy ('Danny'; see Figure 2b), who was standing close to a group of other children. Danny continued with a short dialogue concerning a scenario where a packet of cigarettes has been found. There were two versions of the scenario: one which provided a socially desirable solution to the problem ('Shall we hand them in to the school office?'); and another which suggested a socially undesirable plan of action ('Shall we try one?').

(3) *School corridor scene*: This was an animation of a school corridor (see Figure 2c), lasting for 78 seconds in total. As the viewpoint of the participant

Figure 2 **Scenes from the IVE scenarios (from l–r): (a) a car from the residential street scene; (b) the character of 'Danny'; and (c) a view of the school corridor scene**

progressed down the corridor it was possible for them to see into adjacent classrooms. The participants were first shown an empty corridor and then an increasingly busy corridor which contained animated virtual school children. Ambient noises (such as a bell ringing to signal the end of a lesson and children talking) could also be heard.

Measures

There were two main measures used in the present study:

(1) *ITC Sense of Presence Inventory* (ITC-SoPI; Lessiter et al., 2001): This is a 44-item self-rated questionnaire developed to measure how involved participants feel when experiencing different media; in this case, the IVE scenarios. The inventory includes questions about (1) spatial presence – how physically located the participant felt in the virtual environment; (2) engagement – how involved the participant felt with the content; (3) ecological validity – how natural the environment felt to the participant; and (4) negative effects – unpleasant physiological effects that a participant experienced in the virtual environment (e.g., dizziness). Participants responded to each question on a 5 point Likert scale depending on whether they strongly disagreed (= 1) or strongly agreed (= 5) with the statements.

(2) *Social Attractiveness Questionnaire*: Following each interaction with Danny in the school playground scene, children completed an eight question self-rated 'social attractiveness' questionnaire (Nowak and Biocca, 2003) on a 7-point Likert scale (1 = strongly disagree; 7 = strongly agree) about how much they enjoyed the interaction with Danny. The questionnaire focussed on whether the participant thought Danny could be their friend and whether Danny was the sort of person they'd like to get to know better.

Design and procedure

The virtual reality technology was developed by *Third Eye*™ and worked by casting projections onto the walls and ceiling of a blue-screened room, termed the 'Blue Room'. There were four screens (three walls and a ceiling) that created a backless cuboid, which allowed easy access for the participants. Each screen was three feet wide and two feet high and had an individual projector. Software has been developed to run the four projections in synchrony so that the content on each screen could be stitched together to make an immersive virtual world. All the scenes were animated by professionals and had a strong sense of realism. The floor of the room was made of metal and was slightly reflective and there were four audio speakers embedded in it. A cross was marked on the floor to show the participant where to stand whilst they were in the room. Participants were told they could stop at any time by calling out to the researcher or by stepping out of the back of the room. A brief scene depicting a short journey down a street in central London was shown to familiarise participants with being inside the Blue Room. After checking that the participant felt comfortable, the researcher began the procedure for the test scenes (summarised above). The participants experienced the IVE scenarios in a fixed order as in the sequence listed above.

During the School Playground scenario participants were counterbalanced on whether they first interacted with the Danny who was behaving in a socially desirable way (i.e., Danny recommends handing the cigarettes into the school office) or in a socially undesirable way (i.e., Danny recommends smoking the cigarettes). After each of the playground scenarios the children were asked to fill out the Social Attractiveness Questionnaire (Nowak and Biocca, 2003). On completion of watching all three virtual environments, the participants were accompanied out of the Blue Room to a comfortable seating area, where they completed the ITC-SoPI (Lessiter et al., 2001) measure. For both questionnaires the researcher supervised the children if questions were unclear.

Results

From the ITC-SoPI, mean scores for each group were calculated for factors of spatial presence, engagement, ecological validity and negative effects (see Table 2). The ITC-SoPI showed an acceptable level of within-subjects reliability for spatial presence ($\alpha = 0.93$), engagement ($\alpha = 0.87$) and ecological validity ($\alpha = 0.87$). Negative effects had a lower level of internal reliability ($\alpha = 0.59$). Independent samples t-tests showed that there was no statistical difference between the ASD ($M = 3.3$; $SD = 0.92$) and control ($M = 3.9$; $SD = 0.69$) group for spatial presence, although the trend was

Table 2 **Mean (*M*) scores (Max = 5) and standard deviations (*SD*) by group for factors spatial presence, engagement, ecological validity and negative effects from the ITC-SoPI (Lessiter et al., 2001). TD = Typically Developing group.**

	ASD (n = 10)		*TD (n = 14)*	
	M	SD	M	SD
Spatial presence	3.3	0.92	3.9	0.69
Engagement	3.6	0.77	4.1	0.66
Ecological validity	3.4	1.12	3.8	0.94
Negative effects	2.6	0.77	2.2	0.72

for the control group to score higher, $t(22) = 1.92$, $p = .068$, $d = .73$. Similarly, there was no statistical difference between the ASD ($M = 3.6$; $SD = 0.77$) and control ($M = 4.1$; $SD = 0.66$) group for engagement, but again a trend was observed for the control group to score higher, $t(22) = 1.93$, $p = .067$, $d = .67$. Ecological validity was found not to differ significantly between the ASD ($M = 3.4$; $SD = 1.12$) and control ($M = 3.8$; $SD = 0.94$) groups, $t(22) = 0.89$, $p = .385$, $d = .38$. Lastly, there was no significant group difference for negative effects, $t(22) = 1.27$, $p = .218$, $d = .53$ (ASD group $M = 2.6$, $SD = 0.77$; control group $M = 2.2$, $SD = 0.72$).

Total mean scores were calculated for each group from the desirable and undesirable solution from the Social Attraction Questionnaire (see Figure 3). The Social Attraction Questionnaire was found to have good internal reliability for both the socially desirable playground scenario ($\alpha = 0.93$) and the socially undesirable scenario ($\alpha = 0.96$). Our prediction was

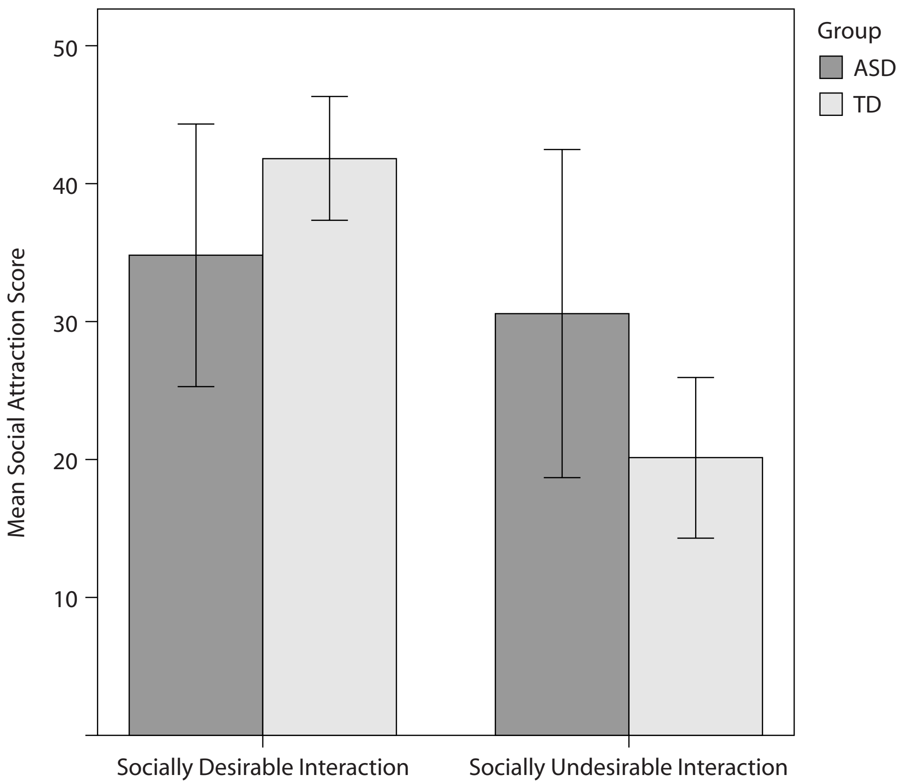

Figure 3 **Mean ratings from Nowak and Biocca's (2003) Social Attraction Questionnaire. Participants watched two virtual environments: one in which the character Danny was acting in a socially desirable way, the other in which he was not. ASD = Autism Spectrum Disorder; TD = Typically Developing.**

that the TD group would assign significantly lower social attraction scores to the socially undesirable than the socially desirable scenario, whereas the ASD group would not. There were no significant order effects shown by either group in terms of reported levels of social attraction being influenced by seeing one type of social scenario prior to the other. Given the relatively small sample sizes, two Wilcoxon tests were conducted to compare group mean social attraction scores between the two conditions: socially desirable versus socially undesirable interaction. The TD group rated Danny in the socially desirable scenario ($M = 41.79$, $SD = 7.72$) as significantly more attractive on the Social Attraction Questionnaire than Danny in the socially undesirable scenario ($M = 20.14$, $SD = 2.69$) ($Z = 3.30$, $p = .01$). However, there were no such significant differences in the ratings of the desirable ($M = 34.8$, $SD = 13.29$) and undesirable ($M = 30.6$, $SD = 16.65$) social scenarios by the ASD group.

Discussion

As an important first step in making recommendations about the potential of IVEs in autism education it is necessary to demonstrate that individuals with ASD become involved or 'present' in virtual environments in the same way that typically developing children do and that they do not show any negative physiological responses. Our results from the ITC-Sense of Presence Inventory (ITC-SoPI) show that children with ASD can operate within, and become involved in, the content of an IVE in the same way as typically developing children. Moreover, if presence can be regarded as a quasi-measure of attention in virtual worlds (Waterworth and Waterworth, 2001) then our findings show that children with ASD are attending to the content and requirements of the virtual environment.

Children with ASD responded with similar levels of spatial presence as the typically developing children, suggesting that they felt transported into the VE. Indeed, one child with ASD spontaneously reported it '*felt like I was there in the playground rather than thinking it was a computer*'. This implies that well designed IVEs can be highly veridical experiences but also safe places to assess and educate children with ASD. The level of engagement with the content of the IVEs was also similar for the two groups, suggesting that the animated sequences were suited to the children's preferences. The design of the virtual environments was completed in full consultation with children, as well as the autism education stakeholder community, meaning that the animated scenes were suited to our target age group. It will be important for future studies to take similar inclusive-design approaches so that the children are fully engaged with the content, allowing for the best outcomes in their learning. There were trends in the data for the control group to score slightly higher than the ASD group on measures of spatial presence and engagement, and so future studies will need to explore whether with larger samples significant group differences emerge.

There were no group differences on the ecological validity subscale of the ITC-SoPI, suggesting that children with ASD accepted that what they saw could happen in real life. This finding is important if VEs are to be used in the future to assess and improve core skills so that children with ASD can take what they have learnt in virtual environments and generalize to real life scenarios. Lastly, there were no group differences in reports of negative effects from the ITC-SoPI and so children with ASD did not feel particularly nauseous or dizzy as has been previously reported when head-mounted virtual reality displays have been used (Regan and Price, 1994). Overall the findings from the ITC-SoPI are encouraging in that children with ASD showed typical levels of presence within a VE, without reporting any unpleasant sensory experiences.

We also explored whether real world social difficulties for children with ASD can be imitated and assessed in an IVE. Children were asked to make ratings of 'social attractiveness' (Social Attraction Questionnaire; Nowak and Biocca, 2003) about the virtual character Danny, who was shown in a socially desirable and undesirable scene (handing in cigarettes to the school office and encouraging the participant to smoke them, respectively). Typically developing children rated Danny in the socially desirable scenario as a significantly more socially attractive friend than the Danny in the socially undesirable scenario, but there was no significant difference in ratings for the children with ASD. The lack of awareness children with ASD showed to the social cues expressed by Danny within the virtual playground is striking and may reflect real world difficulties they have in interpreting the intentions of their peers.

In addition to our positive findings from the formal measures employed on the study, there were also many anecdotal positive comments from parents and children. For example, parents of participating children who worked in schools encouraged their colleagues to view the Blue Room with the hope of using it in future projects. One parent commented that her son had stopped taking part in research because he was not interested in the content but the Blue Room was different because the child enjoyed the nature of the project and the family could see clear educational applications for the technology. Overall, these accounts support a very encouraging picture for the potential uses of this technology in assessing and educating social skills in individuals with ASD.

Limitations

One of the main limitations of the study was the fact that participants were passive observers of the scenes presented in the Blue Room and so could not influence the timing and nature of the scenarios depicted. This was a function of the stage of development of this particular technology rather than a deliberate omission. Nonetheless, participants gave high ratings, on average, on presence measures relating to engagement and ecological validity, suggesting that the Blue Room offers a strong perceptually immersive experience despite the limitation on direct interaction. In addition, we did not include a measure of frequency of use of video games at home, which could be an important factor in terms of how young people interpret, and respond to, virtual reality stimuli. This is clearly an important measure to include in future research because it will be essential to determine whether any distinctive or different patterns of responding could, at least in part, be attributed to greater familiarity with technology in general rather than specific effects in relation to a particular technology.

Future applications

Of course, there are always additional considerations regarding the uses of technology for learning, not least the accessibility and usability of innovative resources for schools and teachers. One of the criticisms of the large VR systems, such as the Blue Room, is that they are too unwieldy and expensive to be of much educational use beyond niche academic research. However, we would argue that the principles from the use and potential of such technologies can be distilled and applied into real world classrooms through the ever-increasing sophistication of available technologies (e.g., through enhanced capabilities of the new wave of interactive whiteboards) as well as developments in making interactive surfaces cheap, flexible and available. A good example of this is the use of inexpensive Wii™ remotes with a projector to configure any surface (such as a wall or table) as an interactive, multi-touch space (see http://johnnylee.net/projects/wii/ for a demonstration). Thus, perhaps now more than ever before, there is a much better chance of being able to transfer knowledge and use from previously 'blue sky'–only applications into classrooms.

In addition, we propose that there could be interesting clinical applications for these kinds of technologies for autism, particularly in relation to providing more authentic and naturalistic means of assessing social difficulties (and therefore targeting interventions and support more appropriately), and also for addressing specific anxieties and phobias, which could be ameliorated through repeated, yet safe and supported, exposure as has been seen in the application of VR to other clinical groups and domains (e.g., Rothbaum and Hodges, 1999).

Conclusions

This study has shown that children with ASD were able to make the links between the images in an immersive virtual environment (the Blue Room) and their everyday experiences. Importantly, they also had no significant negative sensory experiences from being immersed in 'reality rich', perceptually enveloped virtual worlds. Our findings suggest that IVEs can be realistic enough to simulate and assess social situations in which children with ASD self-report as having difficulties with in the real world. In this sense, the Blue Room environments have strong ecological validity and, therefore, potential as future learning tools.

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