Virtual reality in autism: state of the art

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Abstract

Autism spectrum disorders (ASD) are characterized by core deficits in three domains, i.e. social interaction, communication, and repetitive or stereotypic behaviour. It is crucial to develop intervention strategies helping individuals with autism, their caregivers and educators in daily life. To this purpose, Virtual Reality (VR), i.e. a simulation of the real world based on computer graphics, can be useful as it allows instructors and therapists to offer a safe, repeatable and diversifiable environment during learning. This mini review examines studies that have investigated the use of VR in autism.

KEY WORDS: autism spectrum disorders, virtual reality, virtual environment, rehabilitation.

Autism spectrum disorders (ASDs) are a group of pervasive developmental disorders characterized by core deficits in three domains, i.e. social interaction, communication, and repetitive or stereotypic behaviour (American Psychiatric Association, 2000), occurring more often in boys than girls (4:1). There has been a significant increase of ASDs over the past decades, with an incidence of approximately 4 per 10 000 to 6 per 1000 children (La Salvia & Tansella 2009; Milovancevic *et al*., 2009; Faras *et al*., 2010). The causes of autism remain largely unknown, but there is evidence that genetic, neurodevelopmental and environmental factors are involved, alone or in combination, as possible causal or predisposing effects of developing autism (Brambilla *et al*., 2003, 2004; Pensiero *et al*., 2009; Mengotti *et al.,* 2011). Although the degree of impairment among individuals suffering from autism may vary, the impact on affected individuals and their families is generally life-changing (Newschaffer *et al.*, 2007). Most studies of ASDs focused on epidemiology, genetics and neurobiology, but more intervention research is needed in order to help individuals with autism, their caregivers and educators (Goodwin, 2008). In this context, it is crucial to develop tools for neurocognitive habilitation enabling children with ASDs to increase their ability to perform daily-life activities. A rather promising tool has recently emerged in many domains of rehabilitation, namely Virtual Reality (VR) (Parsons *et al*., 2009; Holden, 2005). VR is a simulation of the real world based on computer graphics and can be used as an educational and therapeutic tool by instructors and therapists in order to offer children a safe environment for learning. Virtual Environments (VEs) simulate the real world as it is or create completely new worlds, and provide experiences that can help patients understand concepts as well as learn to perform specific tasks, which can be repeated as often as required (Chittaro & Ranon, 2007). Furthermore, VEs are better suited for learning than real environments since they (1) remove competing and confusing stimuli

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from the social and environmental context, (2) manipulate time using short breaks to clarify to participants the variables involved in the interaction processes and (3) allow subjects to learn while they play (Vera *et al.,* 2007).

The realism of the simulated environment allows the child to learn important skills, increasing the probability to transfer them into their everyday lives (Strickland *et al.*, 1997; Mc Comas *et al.*, 1998; Wang & Reid, 2010). Until recently, head mounted displays (HMDs) were typically used in VR to increase the feeling of immersion in the VE. Unfortunately, besides being a more costly and less comfortable solution with respect to ordinary computer monitors, HMDs may also cause "cyber-sickness" (Parsons *et al.*, 2004; Wang & Reid, 2010), whose most common temporary symptoms include nausea, vomiting, headache, drowsiness, loss of balance, and altered eye–hand coordination (Holden, 2005). However, VEs can also be visualized and explored using an ordinary computer monitor connected to a common personal computer (desktop VEs). The user can move in the VE using common input devices, such as keyboard, mouse, joystick or touchscreen, and interactions between the child and the therapist are also supported (Holden, 2005; Standen *et al.*, 2002). Desktop VEs are more affordable and accessible for educational use, and less susceptible to the symptoms of cyber-sickness.

The literature is increasingly recognising the potential benefits of VR in supporting the learning process, particularly related to social situations, in children with autism (Strickland *et al.*, 1996; Strickland, 1997; Parsons *et al.*, 2002; Goodwin, 2008; Ehrlich & Miller, 2009). Research has analysed the ability of children with ASDs in using VEs and several studies, except one (Parsons *et al.,* 2005), suggested that they successfully acquire new pieces of information from VEs. In particular, participants with ASDs learned how to use the equipment quickly and showed significant improvements in performance after a few trials in the VE (Strickland *et al.*, 1996; Strickland, 1997; Parsons *et al.,* 2004).

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Two studies, using desktop VEs as habilitation tool, have recently been carried out to teach children how to behave in social domains and how to understand social conventions (Mitchell *et al.,* 2007; Herrera *et al.,* 2008). The first study reported that, by using a VE which reproduces a "virtual cafè" to teach social skills, the speed of execution of the social task in the VE improved after the repetition of the task. The same study showed an improvement of social skills understanding after the VE session. The second study employed a VE which reproduces a "virtual supermarket" with several exercises about physical, functional and symbolic use of objects, finding that the performance of participants, assessed by specific tests, increased after the VE intervention and one child was able to transfer the acquired skills to the real environment. Further studies were carried out using Collaborative Virtual Environments (CVEs) which support multiple simultaneous users, in particular the patient and the therapist, who can communicate with each other through their avatars. CVEs have been used to examine and investigate the ability to recognize emotions (Moore et al., 2005) and also to improve social interaction, teaching students how to manifest their emotions and understand those of other people (Cheng & Ye, 2009). These studies found respectively a good performance in identifying emotions and an improvement in social performance after the intervention (Table 1 summarizes the major behavioral studies involving VR).

The use of VR tools for habilitation in autism is therefore very promising and may help caretakers and educators to enhance the daily life social behaviours of individuals with autism. Future research on VR interventions should investigate how newly acquired skills are transferred to the real world and whether VR may impact on neural network sustaining social abilities.

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Table I: Behavioural studies investigating VR in patients with Autism spectrum disorders (ASDs) and healthy subjects.

Study	Subjects (N)	Age (Years, range)	Equipment	Dependent variables	Descriptions of results
Strickland et al.,(1996)	2 patients	7.5-9	HMD (14-21 x 3-5 minutes session)	Level of acceptance of HMD equipment, ability to complete task and pay attention to the VE (i.e: ability to identify cars and colors, when asked, in three different street scenes).	Children wore the helmets without problems and completed the tasks correctly (i.e they identified car color correctly also when they saw different street scenes).
Strickland, (1997)	2 patients	7.5-9	HMD (40 x 5 minutes session, during a six week period)	Level of acceptance of HMD equipment, ability to identify a virtual object (i.e cars in street scene) and ability to find an object in a VE.	Children were able to use the VR equipment and their ability in the task suggest that VR is useful as learning tool (i.e both children identified car colors and found the hidden object).
Parsons et al., (2004)	36 subjects : 12 patients (VIQ:68.9- PIQ: 91.9) 12 (VIQ:70.3) 12 (PIQ:92.1)	13-18	Desktop monitor with mouse (5 session)	Use and understanding of VE (performance: time and errors made) in training trials and in a "Virtual Cafè".	Participants with ASDs learned to use the equipment quickly and showed significant improvements in performance after a few trials in the VE.
Parsons et al., (2005)	34 subjects : 12 patients (VIQ:67.3- PIQ:88.4) 11 (VIQ : 68.5) 11 (PIQ : 89.9)	13-18	Desktop monitor with joystick and mouse	Participants' adherence to social norms such as not walking on the grass, or not walking between two people (performance, participant explanation of routes taken).	A significant minority of the patients adhered to the social norms, others displayed substantial "off-task" behaviour and a limited understanding of the VE.
Moore et al., (2005)	34 patients	7.8-16	Desktop monitor with mouse	Usefulness of CVE for children with autism and ability to recognize emotions (using tasks such as recognizing the emotion expressed by the avatar, identifying the emotion appropriate to the context or identifying the context in which to express the emotion).	Most participants (30 of 34) were able to use the avatars and to understand and recognize emotions appropriately.
Mitchell et al., (2007)	7 patients	14-16	Desktop monitor with mouse (2 x 30-50 minutes sessions)	Social skills understanding during sessions which took place in a "Virtual cafè" using tasks such as "find a place to sit down". Video Measures: participants saw videos, Cafè or Bus, before and after intervention and they provided verbal explanations of how they would behave in the social situation proposed by video.	Improved ability and faster completion of successive tasks' session during intervention. Improved ability in at least 1 video in reasoning about where to sit and choosing where to sit after intervention.
Herrera et al.,(2008)	2 patients	8-15	Touchscreen (28 x 20-30 minutes sessions, 3 session per week)	Ability in understanding symbolism and imagination (Virtual supermarket tool with tasks such as "I'm going to act as if…") using specific tests to asses the increase in performance after intervention).	Significant advances in performance after treatment for both children in functional, symbolic, imagination understanding. For one children, as reported by parents and professional, acquired skills were generalized to

					the external environment.
Cheng *et al., (2010)*	3 patients	7-8	Desktop monitor with mouse (5 x 30-40 minutes session)	Social competence (recognition and expression of feelings; recognition of non-verbal behaviors; eye contact; appropriate manner, able to listen others) using a VE which reproduces a "Virtual Classroom and Outdoor scene".	Participant's performance in social competence improved after the intervention, and for two children improvement persisted into follow-up (10 days after).

ASDs: Autism Spectrum Disorders; VIQ: Verbal IQ; PIQ: Performance IQ; HMD: Head mounted display; VE: Virtual Environment, VR: Virtual Reality; CVE : Collaborative Virtual Environment.

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