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This Section of *Epidemiology and Psychiatric Sciences* regularly appears in each issue of the Journal to describe relevant studies investigating the relationship between neurobiology and psychosocial psychiatry in major psychoses. The aim of these Editorials is to provide a better understanding of the neural basis of psychopathology and clinical features of these disorders, in order to raise new perspectives in every-day clinical practice.

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Virtual reality in autism: state of the art

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Autism spectrum disorders are characterized by core deficits with regard to 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. For 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.

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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 few decades, with an incidence of approximately 4 per 10 000 to 6 per 1000 children (Lasalvia & Tansella 2009; Pejovic 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 (Pensiero *et al.* 2009). Although the degree of impairment among individuals suffering from autism may vary, the impact on affected individuals and their families is generally life-changing. Most studies of ASDs are focused on epidemiology, genetics and neurobiology, but more intervention research is needed to help individuals with autism, their caregivers and educators. 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). 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 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

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Table 1. *Behavioural studies investigating VR in patients with ASDs and healthy subjects*

Study	Subjects (*N*)	Age (years, range)	Equipment	Dependent variables	Description of results
Strickland *et al.* (1996)	Two patients	7.5–9	HMD (14–21 × 3–5 min session)	Level of acceptance of HMD equipment, ability to complete a task and pay attention to the VE (i.e. ability to identify cars and colours, when asked, in three different street scenes).	Children wore the helmets without difficulty and completed the tasks correctly (i.e. they identified the colour of cars correctly also when they saw different street scenes).
Strickland, (1997)	Two patients	7.5–9	HMD (40 × 5 min 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 suggests that VR is useful as a learning tool (i.e. both children identified car colours and found the hidden object).
Parsons *et al.* (2004)	Thirty-six subjects: 12 patients (VIQ:68.9–PIQ: 91.9) 12 (VIQ:70.3) 12 (PIQ:92.1)	13–18	Desktop monitor with mouse (5 sessions)	Use and understanding of VE (performance: time and errors made) in training trials and in a 'virtual cafe'.	Participants with ASDs learned to use the equipment quickly and showed significant improvement in performance after a few trials in the VE.
Parsons *et al.* (2005)	Thirty-four 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)	Thirty-four 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)	Seven patients	14–16	Desktop monitor with mouse (2 × 30–50 min sessions)	Social skills understanding during sessions that took place in a 'virtual cafe' using tasks such as 'find a place to sit down'. Video measures: participants saw videos, cafe 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 one video in reasoning about where to sit and choosing where to sit after intervention.

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Table 1. *Continued*

Study	Subjects (*N*)	Age (years, range)	Equipment	Dependent variables	Description of results
Herrera *et al.* (2008)	Two patients	8–15	Touch screen (28 × 20–30 min sessions, 3 sessions 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 child, as reported by parents and professional, acquired skills were generalized to the external environment.
Cheng *et al.* (2010)	Three patients	7–8	Desktop monitor with mouse (5 × 30–40 min session)	Social competence (recognition and expression of feelings; recognition of non-verbal behaviours; 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 later).

ASDs, autism spectrum disorders; VIQ, verbal IQ; PIQ, performance IQ; HMD, head-mounted display; VE, virtual environment; VR, virtual reality.

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 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, 1997). 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), whose most common temporary symptoms include nausea, vomiting, headache, drowsiness, loss of balance and altered eye–hand coordination. 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 touch screen, and interactions between the child and the therapist are also supported. Desktop VEs are more affordable and accessible for educational use, and less susceptible to the symptoms of cyber-sickness.

The literature is increasingly recognizing 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). Research has analysed the ability of children with ASDs in using VEs and several studies, except for one (Parsons *et al.* 2005), suggesting 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).

Two studies, using desktop VEs as a 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 that reproduces a 'virtual cafe' 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 understanding social skills after the VE session. The second study employed a VE that reproduces a 'virtual supermarket'

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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) that 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, 2010). These studies, respectively, found a good performance in identifying emotions and an improvement in social performance after the intervention (Table 1 summarizes the major behavioural 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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