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Making Interaction Accessible: Virtual and Augmented Reality for Eye Contact Training in Autism Spectrum Disorder

Rendere l'interazione accessibile: realtà virtuale e aumentata per il contatto visivo nell'autismo

Sezione Monografica

ABSTRACT

People with Autism Spectrum Disorder frequently struggle with eye contact, i.e. the ability to reciprocate another person's direct look. This restricts their access to social interaction and thus constitutes a considerable barrier to social inclusion. This paper explores the possibility to employ virtual and augmented reality to devise training programs aimed at improving eye contact skills in the population at stake.
The paper starts with a critique of the usage of virtual reality, highlighting some of its limitations: most importantly, the discomfort generated by most headsets. Hence, the paper proposes a shift towards augmented reality. By comparing the two technologies, it shows that the latter, in addition to proving at least as effective as virtual reality, is also more tolerable, both physically and socially, and easier to incorporate into everyday social settings. Augmented reality, the paper concludes, may become an important component of future interventions targeting social inclusion for people with Autism Spectrum Disorder.

Keywords: virtual reality, augmented reality, direct look, social skills, gaze aversion, autism

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1. Introduction

Eye contact, i.e. the condition established when two persons look at each other directly in the eyes, has been claimed to play a key role in human beings' social life (Argyle & Cook, 1976; Conty *et al.*, 2016). Human infants show exceptionally early sensitivity to eye contact and they perform enhanced face processing at brain level when exposed to faces with direct gaze (Farroni *et al.*, 2002). Mutual gaze dynamics appear to play a foundational role for subsequent forms of interaction, and they keep serving a variety of functions even in the presence of later-developing social skills (Schilbach, 2015). In short – at least in Western societies – we depend on eye contact heavily when it comes to developing a fully functional intersubjectivity, which in turn is crucial in achieving social inclusion.

Sustaining the gaze of others, however, can prove troublesome for some people. Among them are those affected by Autism Spectrum Disorder (ASD).

According to the DSM-5 (American Psychiatric Association, 2013), ASD is characterized by «persistent deficits in social communication and social interactions across multiple contexts». One of the manifestations of these deficits is precisely «abnormalities in eye contact» (p. 50), in the form of what is sometimes referred to as «gaze aversion». Being unable or unwilling to look at others in the eye prevents people with ASD from gathering important situational, emotional, and communicational cues, thus reducing their chances of successful interaction. Thus, contrary to common prejudice, social withdrawal in this population may be the result of lacking social competence rather than a preference or a deliberate choice (Baczewski & Kasari, 2021). In addition, the inability to reciprocate the others' look can hinder people with ASD in their professional life. Indeed, eye contact has been found to be important for obtaining and keeping a job (Sahin et al. 2018c) – which is crucial in terms of one's autonomy (Vona *et al.*, 2022). On this grounding, and since childhood social engagement is considered one the most significant predictor of adult social outcomes, it is deemed important to "plan ahead" and design interventions aimed at improving eye contact in people with ASD from an early age (Yoshikawa *et al.*, 2019).

Just like any other skills, social skills – including eye contact – can be *trained*. In fact, this happens frequently and most notably in the corporate domain, in which specific programmes are developed to this aim. Some of these programmes rely on virtual reality (VR), a technology that utilizes head-mounted displays (HMD) or projection systems (CAVE) in order to plunge the users into 360-degree, immersive, and often interactive environments. Examples are Bodyswaps (https://bodyswaps.co/) and VirtualSpeech (https://virtualspeech.com/). This business-oriented usage of VR for social skills training has prompted some scholars to test a similar usage of the same technology in the specific domain of ASD, with some studies concentrating on eye contact in particular.

As it emerges from the most recent literature reviews on the topic (Dechsling *et al.*, 2021; Mosher *et al.*, 2021), in the field of application at stake VR appears to overshadow a related yet distinct technology, i.e. augmented reality (AR). In fact, studies using AR are comparatively less frequent (Moscher *et al.*, 2021); moreover, they tend to be assessed together with studies using VR, which effaces the specificity of both (Dechsling *et al.*, 2021). This paper aims at discussing each type of studies separately, and eventually at proposing augmented reality as a more suitable alternative than virtual reality for eye contact training for people with ASD.

2. VR in ASD Intervention: Promised Land, or Slippery Slope?

The usage of VR in the domain of ASD is in line with its recent dissemination in mental healthcare, where it has proved successful in the treatment of a variety of disorders (Freeman *et al.*, 2017; Park *et al.*, 2019). What makes this technology appropriate with regard to ASD more specifically has been pointed out recently by Lahiri (2020). In the author's view, among the relevant features of VR in this regard are *controllability* and *reduction in human interaction*. Controllability implies that VR environments can be programmed so as to modulate the intensity of sensory stimulation in relation to individual needs. This is important because people with ASD tend to be prone to «hyper- or hypo-reactivity to sensory input» (American Psychiatric Association, 2013, p. 50). Reduction in human interaction, for its part, is relevant because people with ASD usually feel comfortable with predictable situations, while interactions with real humans – on the contrary – are often unpredictable. Virtual agents are much more rigid than human beings, but this – though paradoxical – can afford people with ASD better chances of successful interaction.

The literature on technologically implemented social skills training in the population group at stake has been recently reviewed by Dechsling and colleagues (2021) and Mosher and colleagues (2021). The two reviews cover the 2010-2020 and 2000-2020 periods respectively and they commonly used as inclusion criteria, among others, the usage of so-called immersive technologies and the involvement of people with ASD as participants. Only peer-reviewed studies were considered. Mosher and colleagues excluded studies with no educational setting or scope. Based on their requirements, the two reviews identified respectively 49 and 41 studies.

The focus of the present paper, however, is more specific compared to these works. Therefore, among the identified studies, I am only taking into account those that a) focus on eye contact, or broader social skills in which the gaze nonetheless plays a primary role; *and* b) employ VR in a strict sense, i.e. delivered by means of HMD or CAVE. This last selection criterion determines a drastic reduction in the number of studies considered, as the term «VR» and the attribute «immersive» abundantly used in titles often actually refer to desktop-based technologies – which, as such, are not immersive in a proper sense. Having applied these two additional requirements, my further selection comprises four papers (Jarrold *et al*., 2013; Halabi *et al.*, 2017; Ravindran, 2019; Herrero & Lorenzo, 2020). To these, I am adding another which neither of the cited reviews include (Elgarf *et al.*, 2017).

In most of the five resulting studies, participants were children, in line with an observed tendency to focus more on them than on adults (Ward & Esposito 2019). Also, samples were usually small, which reflects the difficulties in recruitment that is typical of this research field (Herrero & Lorenzo 2020).

In two cases, although it was recognised as an index of successful social interaction, eye contact was only *monitored* during the VR experience, without being the object of a training intervention whose outcomes could be measured by means of pre/post comparisons. Therefore, these studies are not discussed below. The remaining three can be used to draw some provisional conclusions and sketch out some possible future directions.

Elgarf and colleagues (2017) developed and tested an interactive game called "I-interact" specifically designed for gaze training. The basic mechanism of this application consists in tricking the users into making eye contact with avatars located in front of them. For instance, in the first level of the game, a female virtual character facing the users asks them to remove butterflies from her face. By following the character's instructions, the users end up making eye contact before realising they are doing so. The participants (4 children with autism or social behaviour problems, aged 8-13) engaged in six gaming sessions over a period of three weeks and underwent pre- and post-test assessment of their eye contact behaviour. Three out of four participants showed an improvement, defined by the number of positive eye contact trials before and after intervention.

Ravindran and colleagues (2019) tested the joint attention module of a commercially available VR system for social skills training in ASD. In this module, children interact with virtual character in a safari-themed environment, having to respond appropriately to her cues. For instance, they may have to look at her and then direct their gaze at an animal she is pointing at. In the experiment, participants (12 children or adolescents on the autism spectrum, aged 9-16) completed 14 training sessions over five weeks. At the start and at the end of the training, they underwent a joint attention assessment which included an evaluation of their ability to make eye contact. At the end of the training, seven participants demonstrated an improvement in this ability, and four a «pronounced» improvement.

What these studies suggest is that VR can indeed be effective in improving eye contact skills in people with ASD. However, studies comparing different implementations of VR (e.g. HMD or CAVE) raise the key, yet underestimated question, of *which* VR is actually in play**.**

Halabi and colleagues (2017) developed an application in which users have to respond appropriately to a virtual teacher greeting them. To do so, children have to address the teacher and greet him in return, with their response time being recorded by the system. The authors tested three different implementations of their application: desktop, HMD, and CAVE. In the first case, participants used the application on a computer screen. In the second case, they wore an immersive headset. In the third case, they were inside a projection-based VR display in which interactive images are projected onto the walls of a room. In a CAVE, users do not usually wear a headset, but are equipped with 3D glasses which make the projected images three-dimensional, while a motion tracker detects their movement and updates the images accordingly. In the experiment, all participants (3 autistic and 7 neurotypical children) tried all the three versions of the VR application. The participants' satisfaction with each version was rated by means of a post-experience questionnaire, while their performance was rated by measuring their response time in greeting the virtual teacher. With regard to the autistic children, the results indicated that they liked CAVE more than HMD, and HMD more than desktop. As for their performance, it was best in the CAVE, followed by desktop and, lastly, by HMD.

This outcome is in line with what found by Elgarf and colleagues (2017) in the second part of their study discussed above. In fact, the authors presented the "I-interact" game to a second group of children with ASD (4, aged 14-15) this time both in an HMD version and in a desktop version. A post-experience questionnaire revealed that the children enjoyed the latter more than the former. As for Ravindran and colleagues (2019), it is true that the participants were reported to tolerate or even enjoy the HMD for most of the time. However, they were not provided any alternative option to compare this technology to.

These data, though quantitatively insufficient to draw any definitive conclusions, draw attention to an issue that should not be overlooked, given that – in most cases – speaking of VR means speaking of HMDs. That this type of device may not be appreciated by people with ASD (at least when they are offered a choice) should raise the question of whether VR is actually the best option for training programs for the specific users at stake. In fact, it is hard not to suspect that discomfort in any training setting may prove distracting and affect the trainees' performances, thus defeating the purposes of the training itself.

3. Beyond VR: AR in ASD Intervention

What Elgarf and colleagues put forward as an explanation for why the children with ASD may not have liked using the HMD is a lack of control over the device. However, a more immediate explanation may be that – as a matter of fact – the HMD is a cumbersome, heavy, and perceptually challenging device. Wearing an HMD implies having one's head wrapped in tight straps and one's forehead and cheeks compressed by the device, which causes hard-to-ignore tactile sensations of pressure. Moreover, once "inside" the HMD, the audio-visual stream (which is inescapable, unless one physically removes the visor) flows right in front of one's eyes. These factors, possibly challenging for any type of user, may create even more discomfort in people with ASD, who – as observed above – are prone to hyper- or hyposensitivity. Future training programs for people with ASD should avoid precisely such discomfort.

In this regard, a first plausible option may be insisting on VR, yet privileging its CAVE-based version, which would avoid the use of headsets. CAVE systems, however, are complex to set up, and therefore not very common. Moreover, and most problematically, they are not *portable*. In practice, this drastically reduces their reach and impact, since moving trainees toward a (possibly remote) training facility is clearly less practical than delivering devices and technologies directly to the trainees. One may think, then, of screen-based technologies, like videogames. However, this option would imply much less realistic interactions, as the users would often engage with 2D characters only.On the other hand, simply going back to real-life training may be too drastic a solution, since it would imply renouncing to the richer and more sophisticated tools of technologically enhanced training just to quickly get rid of its possible limitations.

In this context, a technology that may allow to preserve realism, at the same time granting a sufficient degree of comfort and practicality, is augmented reality. Though the latter is an umbrella term comprising several instantiations of the same technology, what I am referring to here is that type of AR which is supported by so-called smartglasses.

Compared to most VR headsets, smartglasses can be easier to wear and more lightweight. Indeed, some are designed purposely to have these properties, which makes them strikingly similar to regular glasses (examples are those belonging to Google's "Glass" family: https://www.google.com/glass/start/). Moreover, just like most AR devices, smartglasses are specifically meant to avoid "enclosing" people in artificial worlds, and rather to improve their agency in the real one (Wellner, Mackay & Gold, 1993; Pirandello, 2021). In fact, similar to VR, AR is basically a system that creates and fosters interactions with a computer-generated environment. However, unlike the former, the latter does not substitute the real world, but rather complements ("augments") it with usually pretty simple digital components: images, characters, infographics, buttons, widgets, and so on, with which users can engage. These components – rather than "invading" their visual field – are usually set at some distance from the users. Taken together, these factors are likely to make AR smartglasses much less perceptually challenging and distressing to use than most VR headsets. In addition, the essential design of these devices and their "ordinary" appearance arguably make them less conspicuous, and thus more socially acceptable to use in public settings like schools.

Far from being a mere theoretical option, AR for ASD intervention has already started to be tried out on the field. One example is a system called Brain Power System (BPS), later renamed Empowered Brain (EB), tested by Liu and colleagues (2018).

The BPS/EB is an AR system based on the Glass technology which uses two embedded gamified applications to teach users (both children and adults with ASD) social skills ranging from emotional understanding and self-control, to eye contact. The mechanism for training the latter, in particular, detects human faces by means of computer vision algorithms and superimposes on each of them a cartoon face, in order to attract the users' attention. Once they look directly at the cartoon face, this gradually fades, so that users find themselves making eye contact with the human interactor. This is rewarded with "points."

In an exploratory study, Liu and colleagues evaluated the effects of the BPS/EB system, with two children with ASD (aged 8 and 9 respectively) taking part in one training session. Based on their caregivers' assessment, both children improved their eye contact behaviour, one of them «greatly». This result, considering the specific features of Liu and colleagues' training technique, allows a direct comparison between VR-based and AR-based training solutions, at least in one of their possible instantiations. Indeed, the superimposition/fading mechanism proposed is not dissimilar from that devised by Elgarf and colleagues (2017) in their study using VR. Bearing in mind the features of the HMD and the BPS/EB respectively, using the latter may imply affording the users the benefits of the same training strategy, without the discomfort of a bulky technology.

This supposition is supported by a study conducted by Vahabzadeh and colleagues (2018) that focused precisely on the feasibility of the Empowered Brain (EB), together with its efficacy. In the feasibility stage, 4 children with ASD (mean age 7.5) used various apps on the system two times per day for two weeks. All participants were able to complete the two weeks. Importantly, participants also showed decreased irritability, hyperactivity, and social withdrawal.

More explicitly, two additional studies (Sahin *et al.*, 2018a; Sahin *et al.*, 2018b) set to investigate possible negative effects of the EB (Sahin *et al.*, 2018a), and its social desirability and usability (Sahin *et al.*, 2018b). These studies are of outmost importance, because they address the delicate issue of the possibility to frame AR-based interventions in everyday settings like school. Keeping in mind socialization and social inclusion as the ultimate goals of the interventions at stake, in fact, it would make little sense to invest in a technology that is effective, yet inacceptable for public usage, should it be required or happen to take place. In the first study, a larger and more varied sample was recruited, with 18 individuals with ASD aged 4.4 to 21.5 years. 16 participants completed the testing session. 14 participants reported no negative effects, and the discomfort reported by the remaining 2 was mild, transitory, and did not provoke session termination. In the second study, 8 children with ASD aged 6.7 to 17.2 tested the EB system and were asked questions concerning their experience in view of future usage. The participants unanimously reported that they did not feel stressed nor overwhelmed at sensory or emotional level. Also, they all stated they would use the EB system at both home and school.

In short, existing studies support not only the effectiveness of AR, but also – different from VR – its high degree of tolerability for the specific type of users of people with ASD, in terms of both physical comfort and social acceptability.

4. Conclusion

Eye contact is key in several kinds of social interactions. Those with peers and educators allow people to develop their personality and skills, while professional interactions create autonomous, self-sufficient individuals. People with ASD, however, often find it difficult to reciprocate another person's look. Since behavioural interventions in this regard are deemed effective, and the population group at stake tends to be prone to the usage of technology, VR has been employed as a training tool for eye contact. In this paper, I have argued that AR could be a better option in this regard.

First, AR proved at least as effective as VR. In addition to improving eye contact, it showed collateral benefits, like reducing other forms of aberrant behaviour (Vahabzadeh *et al.*, 2018). Second, in contrast to VR, AR was found to be highly tolerable for users, possibly in virtue of the lightweight and non-occlusive devices it relies on. Lastly, AR demonstrated to be socially acceptable and easy to incorporate into ecological settings (Sahin *et al.*, 2018a; 2018b).

Based on this preliminary evidence, and considering that early interventions are key for further development stages (Yoshikawa *et al.*, 2019), I believe that AR applications for eye contact should be further tested in everyday public contexts that are relevant for children, and more in detail in school. School is where children spend most of their day time, and sometimes it is also where they receive the majority of their social stimuli. AR interventions could be conducted with little effort on behalf of teachers or support figures and could significantly increase the quality of both friendly and educational interactions (Sahin *et al.*, 2018).

Further research is needed, particularly in the form of more direct comparisons between AR, VR, and possibly other related technologies. Still, current evidence suggests that AR may come to play a role in making social interaction more accessible for people with ASD.

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