Toward scalable VR therapy solutions for individuals with Autism Spectrum Conditions: Challenges and Opportunities

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ABSTRACT

The usage of VR technology to allow instructors and therapists to offer safe, repeatable and diversifiable learning environments for individuals with Autism Spectrum Condition has recently bloomed in scientific literature. However, despite the encouraging results regarding the clinical effectiveness of this approach to relieve their social anxiety and improve their social & emotional skills, several challenges are still to be addressed from both technological and clinical perspectives to achieve its full potential as a digital therapy. In this paper a description of the most critical challenges together with a suggested set of intertwined research directions is provided. Moreover, a description of the main achievements obtained out of an Innovation project aimed at tackling a subset of these challenges is provided, with a short discussion on the preliminary results obtained on a recent experimental pilot.

CCS CONCEPTS

• Human-centered computing~Human computer interaction (HCI)~Interaction paradigms~Virtual reality

KEYWORDS

Virtual reality, Autism, Sensors, Serious Games, Education

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1 Introduction

Individuals with Autism Spectrum Condition (ASC) typically present some deficits in social communication and are often characterized by the presence of restricted interests and repetitive behaviors. The rate of kids diagnosed with autism is increasing worldwide together with the demand for psycho-behavioral therapies provided by Specialized Centers (SC). Lack of therapies for youth with ASC leads to higher rates of depressed and socially isolated individuals in their adulthood, which may lead them to have troubles in finding a job and gain personal autonomy.

Even though the first research papers exploring the usage of Virtual Reality Environments (VRE) to facilitate skills development of people with ASC can be dated back to the end of nineties [1], only in recent years research activities bloomed around this topic mainly thanks to the wide availability of low-cost headsets and sensors that facilitates more in-depth experimentation of VR within this specific application domain. One of the most important interventions with children and adolescents with ASC is on targeting social skills deficit. Focusing on Social Skills Training, authors in [2] have used meta-analytic methods to compare preliminary evidence for behavioral intervention technologies (BITs-SST) to more traditional face-to-face interventions (F2F-SST). A comparison among a large number of technology-based interventions (including VRE) showed a medium to large effect size for BITs-SST and F2F-SST in improving the social skills of children and adolescents. More importantly, no significant differences between the two intervention modalities, thus paving the way to expand intervention resources and increase access to services that could reduce many of the costs of getting therapeutic services for individuals with ASC and their families.

Previous work shows the potential of VR technology to allow instructors and therapists to offer safe, repeatable and diversifiable learning environments for individuals with ASC [23][25]. However, while a literature survey found that statistical validations demonstrate the feasibility of positive and significant results of VR-based treatments, it remains to be

demonstrated that such interventions are able to train or modify the complete behaviour of the selected individual [10]. Similarly, the long-term effects and benefits of VR treatments for individuals with ASC are still an open question (see [6][7]). In order to achieve a more significant impact of VR to improve the condition of individuals with ASC, a series of challenges are still to be addressed from both technological and clinical perspectives to achieve its full potential as a digital therapy and to address issues such as generalisation, and scalability beyond the proof-of-concept studies.

The aim of this paper is to identify such challenges and to describe opportunities and envision research directions that can create the conditions for a wider acceptance of VRE as a clinical tool for autism. A description of the VR environment developed within the framework of an Innovation-driven project co-funded by EIT Digital (XR4A) is also provided, whose aim is to provide a preliminary exploration of the identified research directions.

2 Main challenges and opportunities in VR for autism

In order to achieve a maturity level of VR for supporting individuals with ASC, a series of challenges are required to be addressed. In this paper we outline these challenges and the opportunities that each of them could provide in the implementation of VR-empowered digital therapies:

Scalability of the VR validation: Most previous studies incorporating VR for autism target a very low number of subjects that render the preliminary findings not generalisable. In [5] authors identified the need for more extensive involvement of clinicians, caregivers and patients as informants. Indeed, the generalisability of their findings was hindered by the lack of standard research design and the possibility to scale-up from preliminary findings. This applies to the duration of treatments, number of sessions and participants required for guaranteeing the results' reliability [6] and is confirmed also in other scientific works [3][7]. In order to overcome this issue, future studies should concentrate in organising longitudinal Randomized Controlled Trials (RCTs) involving enough participants to achieve statistical relevance required for reproductivity of the studies and generalisations at larger scale.

Predictive therapy: Through the acquisition and analysis of subjects data in larger longitudinal trials, it would be possible to augment the knowledge about how patients interact in controlled VR environments and how these interactions could impact in their therapy. The data acquired could be used to train AI- machine learning models to infer patients' state and eventually to improve treatment by implementing personalised, predictive therapy approaches. The unique attributes of each individual with ASC suggests that a data-driven approach to therapy is of utmost importance in order to better understand how they interact responding to different interventions and services [18].

Advanced digital excipients for therapy: A major opportunity for realising the potential of virtual reality-enabled digital therapeutics for ASC is the use of richer sensing and actuating tools [19]. Current research is aiming to design a new generation of headsets that could be used as both, sensing and delivering platforms for immersive environments. A major functionality of these devices would be the detection of a wider range of parameters within the headsets such as movement of face muscles [28], detection of skin conductivity, high resolution eye-tracking [29], temperature sensing, inertial sensors, heart rate, electroencephalography (EEG) [27], respiration rate and speech recognition among others. The combination of these signals could provide better understanding of the patient's state during therapy (e.g. emotional state [30]) and may be utilised as bio-feedback signals to improve the interaction and engagement towards achieving the therapeutic goals.

Serious games and affective computing: Despite the large amount of recent scientific works on the application of VR to improve social and emotional skills of individuals with ASC, in most cases the individual is exposed to immersive scenarios duplicating real-life settings. However, the development of VR scenarios leveraging design principles around the concept of serious games has provided evidence about a stronger engagement by the participants [7]. The recent rise of the affective computing approach in developing VR games with therapeutical objectives is a promising direction toward the deployment of engaging platforms, especially when the user group is composed by children and youth with ASC, a target composed in large part by passionate videogamers [20]. In particular the implementation of multi-player VR settings is a very promising direction since it facilitates a stronger interactions among the players involved and opens interesting research directions toward the involvement of mixed groups composed by normo-typical and ASC individuals.

Conversational agents in VR: The adoption of chatbots and conversational agents to benefit individuals with mental health issues has been largely studied in scientific research [21]. Many authors have explored their application as a therapy tool for people with ASC, i.e. as one of the components of the so-called“social robots”, robots that can interact with humans and the environment, thanks to the continuous AI-based analysis of audio and video data collected in real-time [9] or as a conversational agent facilitating social skills development [22]. The application of virtual agent technologies associated to a number of Non-Player Characters (NPCs) within a VR setting

will therefore be an important element to both relieve the therapist intervention during the session as well as a tool to measure and evaluate social communication skills improvement of the individuals with ASC.

Uptake in clinical practice: As for other types of therapies, the adoption of VR therapy and its uptake in clinical practice could be realised only after a clear demonstration of its efficacy through successful clinical trials. In [26] a first RCT examining a combination of VR environment and one cognitive behavioural therapy session to address specific phobias in young people with ASC is reported. Despite the encouraging results obtained in the trial, the additional impact of VR over traditional therapy remains unclear, and the cost-effectiveness needs to be assessed. Moreover, the lack of standardisation of interventions and diagnosis/ASC classification tools emerges clearly in literature reviews on the topic [11][10]. A possible approach to tackle these challenges is by the implementation of a digital therapeutics research framework that could enable the identification of adequate clinical protocols designed as digital active ingredients that could take advantage of VR technologies as digital excipients. The assessment of clinical validity and efficacy of such interventions and the identification under which circumstances could provide clear benefit for therapy, would be the key element for creating clinically certified solutions to be employed as a complement to mainstream therapeutic approaches.

Ethics and safety: As for other digitally-empowered therapies management, the use of VR for individuals with ASC would require a thorough investigation in the ethical and safety issues involved in the use of the proposed technologies. The envisioned future solutions should consider privacy-by-design approaches in which patients personal data would be also kept confidential and secure through adequate technical and organisational provisionings (i.e. such as anonymisation, pseudonymisation, data encryption, access control, etc.). In the same way, future solutions and their implementation should consider specific mechanisms to avoid stigmatisation of users. Moreover, a minimum ethical, security and safety provisioning in future developments should consider as a minimum requirement the guarantees proposed by GDPR regulation to protect personal information and patients rights; other more strict considerations could be considered for the specific case of ASC in which the target patients decisional and communication capabilities may be more compromised due to the specific characteristics of the disease and the fact that therapy is suggested already for underaged patients.

3 XR4A: VR-based tele-therapy for Autism

In this section we present the XR4A system as a preliminary development intending to address some of the challenges and opportunities mentioned before. XR4A is an Innovation-driven project co-funded by EIT Digital aimed at developing an XR-based tele-therapy solution for teens and young adults with neurodevelopmental disorders like autism [24]. Compared to the large majority of scientific publications on VR for autism, the developed solution focuses more on exploring its viability as a tool for remote therapy. Moreover, the developed platform within XR4A is built in the perspective of tackling several of the opportunities identified in Sect. 2, in particular scalability of the validation, detection of emotional status, predictive therapy and serious games.

The implemented VR solution focuses on a multi-player immersive setting where a small group of teens can play and interact with each other through their digital avatars. Moreover, the therapist is also participating within the immersive setting with her own avatar acting as a facilitator very similarly to what happens in traditional settings in presence. One of the most critical issues in a tele-therapy setting is the possibility for the therapist to have real-time monitoring of the emotional status of each (remote) player, in order to promptly intervene in case a player faces a stressful condition that may be potentially dangerous for her health status and safety. In order to tackle this specific issue, the VR solution developed within XR4A leverages a biometric data analysis performed by collecting heart-rate signals generated by an HRM bracelet.

Compared to most of the VR tools proposed in literature to reinforce social and emotional skills which leverages on the replication of real life settings (like school, canteen, etc), the VR experience developed within XR4A is built around a fantastic game adventure that happens partially on Earth and partially on a foreign planet. The idea is to transport the player into a more engaging setting where the group of teens act as a team of space explorers. The objective of the adventure is to help scientists to retrieve a very rare material available on a planet called “Zentastic” they can use to build an instrument needed to fix the Ozone layer on Earth, thus saving human beings from extinction.

Figure 1 provides a snapshot from the three main VR scenes where the players are involved to accomplish the Mission assigned by the scientists. Each of the VR scenes were designed in collaboration with the therapists of Cooperativa Albero Blu, a Rehabilitation Center based in Italy, and are aimed at facilitating collaborative and problem-solving activities among the teammates as well as to improving their executive functions, e.g. selective attention.

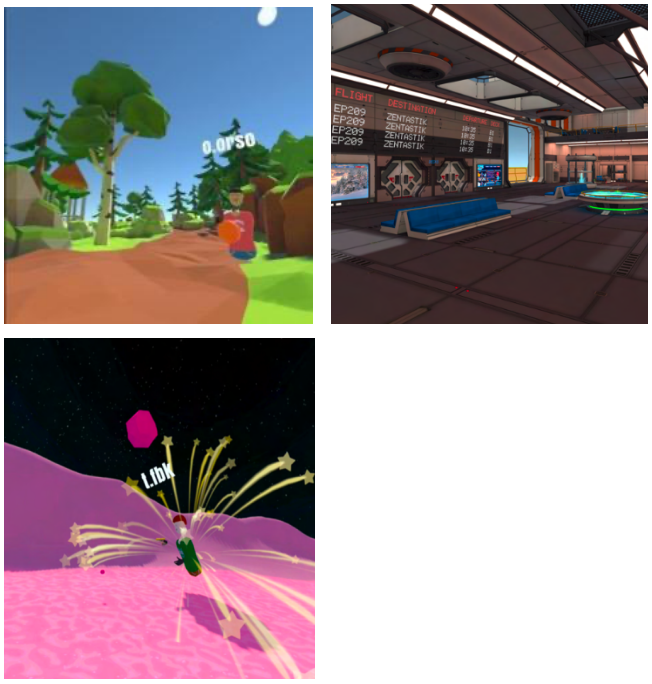

Figure 1: **The three main scenes within XR4A: Coin Hunt (up-left), Space station (up-right), Zentastic planet (low)**

The VR application has been developed with the Unity framework [15], using assets bought on its asset store, and deployed on Meta Oculus Quest 2 headsets. The gaming backend is managed by the Photon Cloud, a SaaS platform that facilitates the synchronization of events among multiple players on a Unity-based VR application [16]. The VR application interacts with Ticuro Reply [17], a platform developed by project partner Reply to facilitate tele-medicine and tele-monitoring, with a web-based front-end that allows to manage the users and schedule the VR session, and a mobile application collecting heart-rate data information from each player via a Polar Sense Verity Heart Rate Monitor bracelet [19]. This platform facilitates the collection and analysis of clinical and environmental data, in full compliance with privacy law (GDPR). In the Ticuro Reply backend, a Machine Learning engine elaborates the flow of biometric data from each player to facilitate stress detection through a number of messages that can be triggered to the therapist involved in the VR scene.

A first experimental pilot has been performed in July 2022 with more than 30 kids and teens from different age groups. The aim of this preliminary assessment was mainly understanding their level of engagement with the game environment and challenges, as well as the therapist's capability to handle different situations in which the teams were involved along the adventure. Analysis of the post session individual interviews with teens showed that there was a high appreciation of the VR game along the dimensions of: engagement, clarity, interaction with objects, movement, user experience and willingness to play again in the VR environment. Ratings on these dimensions on a 1-5 Likert scale (1=low, 5=high) measuring appreciation, reached an average rating equal or above 4 for all dimensions. As a matter of fact, all the feedbacks and insights collected from the interviews with teens and observations of their behaviors in the VR environment during the game have been used to improve the design of the VR game even further.

In XR4A, the data collected during the interactions include a complete log of users movements and interactions in order to conduct a machine learning process for inferring preferences and behaviours for enabling a prediction of users intentions and emotions for a further design of more personalised experiences potentially increasing the user engagement and therapeutic outcomes. XR4A is currently tested within a feasibility study and is intended to be validated for efficacy in a further clinical trial.

The platform developed within the framework of XR4A project will be commercialized by a spinoff of FBK (MEEVA Srl) whose aim is to provide Specialised Centers with a tool enabling digital therapy toward pre-adolescents and teens with autism and other neurodevelopmental disorders.

4 Conclusions

Even though many research papers have provided evidence about the capability of VR technology to allow instructors and therapists to offer safe, repeatable and diversifiable learning environments for individuals with ASC, a number of challenges are still to be addressed from both technological and clinical perspectives to prove its full potential as a digital therapy and to address issues such as generalisation, and scalability beyond the proof-of-concept studies.

In this paper a description of these critical challenges is provided, together with the most promising research directions that could tackle them thanks to latest advances in several fields, i.e. Artificial Intelligence and new generation VR headsets. Some of the identified challenges have been explored within the framework of an EIT Digital project called XR4A whose aim is to develop a VR-based tele-therapy for individuals with ASC that can easily scale while facilitating therapists to evaluate its clinical effectiveness.

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