ABSTRACT

Autism Spectrum Disorder (ASD) is a complex neurodevelopmental disorder characterized by impairments in social communication, reciprocity and understanding the preferences of social partners that can be critical during collaborative task execution. Given the deficits characterizing ASD along with high prevalence of ASD (about 1 in 69 children in India being diagnosed), easy access to appropriate intervention services is critical. However, in countries like India, specialized observation-based conventional intervention services are available only in selected urban pockets. This demands emphasis on carrying out deeper exploration into designing platforms that can make effective intervention services accessible to these individuals. There is consensus that an intensive and structured behavioral intervention program targeting the core deficits in communication skills while considering various social aspects can mitigate some of the difficulties faced by the individuals with ASD. This can possibly result in long term benefits for the target population by bringing positive outcomes in terms of improved social communication and interaction skills.

The conventional observation-based intervention techniques practiced by skilled therapists have been reported to be potent in bringing about such positive outcomes. Additionally, given the heterogeneous nature of the Autism Spectrum, offering an individualized service is essential for the intervention to be effective and this is practiced by trained therapists in conventional intervention settings. However, the limitations such as lack of availability of adequately trained therapists and the exorbitant costs in availing such services can make such intervention inaccessible for the common man. These challenges call for alternative solution in which the technology-assisted platforms can play a significant role in delivering more accessible, intensive, quantified and individualized services.

Researchers have been investigating the use of technology-assisted platforms such as computer based Virtual Reality (VR) and robotic technologies in providing intervention services to the

individuals with ASD. With the rapid progress in computer graphics, it is argued that the computer-based VR technology can be harnessed to provide effective intervention for individuals with ASD. In our current research, we have used computer-based VR technology, due to its flexibility in design, avenue to develop controlled and interactive 3D virtual environments that can project subtle nuances related with various real-life social situations in the form of audio-visual presentation which can be both entertaining and informative for the children with ASD. Also, using VR, we have manipulated some of the social aspects such as proximity and eye-gaze of a virtual character (avatar) serving as a communicator or facilitator.

Further, to facilitate the intervention process, the VR-based system needs to have an ability to obtain quantitative estimates on the affective states of each individual that might offer useful information to therapists. This is important, since the individuals with ASD often demonstrate difficulties in making explicit expression of their affective states in social situations. The VR-based system can be equipped with mechanisms that can tap into one's affective state using some of the implicit cues while being exposed to simulated social situations having varying challenges. One of the ways can be through monitoring one's gaze-related physiology and behavioral looking pattern while individuals interact using the VR-based platform which can be achieved by augmenting the platform with eye tracking technology. In our current research, we have augmented the VR-based social communication platform with eye tracking technology.

While such exploration into the social communication aspects of children with ASD using single-user (single participant with ASD interacting with avatar) VR-based platforms is important, investigation of VR-based social communication skill training using multi-user platforms (multiple participants with ASD interacting with each other using the training platform) is also critical. This is because, instead of interacting with an avatar (simulated character) individually, the multi-user platform will necessitate the multiple individuals with ASD to interact with each

other (using the VR platform). Thus, each individual would be expected to put himself/herself into the shoes of the partner while understanding each other's preference on a topic of interest before reciprocating. This is one of the core difficulties faced by individuals with ASD. Thus, training these children to overcome such difficulties is necessary so as to foster fluid interpersonal social communication, essential for healthy community living.

In my present research, a multi-user VR-based environment was designed as an interactive platform where multiple participants interacted with each other while executing a collaborative task having shared goals. Additionally, one of the important components (that are missing in the currently available systems) during social interaction is to promote the participants to understand each other's preference on a topic of interest while collaboratively executing a task. The multi-user VR environment (developed in my work) can offer a facility to foster interaction among multiple users/players through appropriate reciprocation while understanding each other's preference on a topic of interest thereby helping in successful collaborative execution of a task.

The task required them (multiple users or players) to jointly frame (while deploying interaction strategy based on understanding of each other's preference) a cohesive story by collating glimpses of social situations presented in front of them on a computer-based canvas. Once they completed a task, an avatar (facilitator) empowered by an intelligent engine was tuned to narrate the story framed by knitting the glimpses of the social situations as chosen by the players. Here we used the story narration, since evidences from literature show the potential of short social stories (in VR-based scenarios) in imparting social communication skills in individuals with ASD. The avatars followed social norms as far as proximity and eye gaze were concerned while narrating the stories. Usability studies were conducted by recruiting participants with ASD and TD to investigate the potential of both single-user and multi-user VR-based social communication platforms augmented with eye tracking technology.

Results indicated the acceptability of such platforms by the target population. Additionally, the results of the usability studies show (i) the implications of social aspects such as communicator's proximity and eye-gaze on one's task performance and gaze-related indices during the VR-based task, (ii) the potential of gaze-related behavioral and physiological indices in characterizing individuals with ASD and their TD counterparts, (iii) the potential of VR-based multi-user task platform to empower participants with ASD to perform better within the simulated world (and outside the VR-based environment) and (iv) the underlying linkage between the collaborative performance capability and their gaze-related behavioral indices.

We hope that using such a VR-based technology can help in fostering effective social communication and interaction skills in individuals with ASD. Also, this can serve as a complementary tool in the hands of the therapists involved in Autism intervention. We believe that the novel technology-assisted VR-based multi-user social communication platform promoting mutual understanding of each other's preference (as developed in the present research) can pave a milestone towards offering comprehensive social skill training thereby contributing to the improvement in the community living of our target population.