Head-Mounted Display-Based Virtual Reality Social Story as a Tool to Teach Social Skills to Children Diagnosed with Autism Spectrum Disorder

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ABSTRACT

In this paper, we present a study conducted to investigate the feasibility of using a Head- Mounted Display (HMD) based Virtual Reality (VR) application as a tool to teach social skills to children diagnosed with Autism Spectrum Disorder (ASD). In collaboration with teachers at a school for children and adolescents diagnosed with mental disorders, an HMD VR based social story application was developed with the purpose of teaching children diagnosed with ASD about sharing, turn taking, and theory of mind. Via a Mixed Method Sequential Explanatory Design, the application was evaluated by two teachers who conducted social story sessions on a total of five students diagnosed with ASD. Results indicate that HMD based VR intervention has the potential of teaching appropriate social behavior.

Index Terms: Human-centered computing—Visualization—Visualization techniques—Treemaps; Human-centered computing—Visualization—Visualization design and evaluation methods

1 INTRODUCTION

The most recent edition of the Diagnostic and Statistical Manual of Mental Disorder (DSM-5) describes social communication and social interaction as two of the primary deficits of individuals diagnosed with ASD [4]. More specifically, people diagnosed with ASD display deficits in social and emotional reciprocity and had difficulties adjusting their behaviours to match different social scenarios. As a result, children diagnosed with ASD are often victims of social rejection and targets of bullying, which have a negative impact on their emotional and mental well-being [31]. Social anxiety, depression, and poor academic achievement are some of the consequences of the impaired social communication in the ASD population [6]. These deficits are also associated with lower daily living skills, resulting in a vast number of adults diagnosed with ASD to rely on support from their parents or social services. In the USA, the social cost during the lifespan of an individual diagnosed with ASD is 3.2 million dollars, consisting mainly of adult care services and lost productivity [12]. Furthermore, the prevalence of ASD has substantially increased during the last two decades [8], showcasing the importance and agency of Social Skills Training (SST) interventions to help children diagnosed with ASD towards an independent and comfortable adulthood. The National Professional Development Center on Autism Spectrum Disorder describes SST as techniques developed to teach groups or individuals diagnosed with SSD ways to appropriately interact with other individuals. These methods involve instructions on basic social behaviours through role-playing, practising and feedback [30]. Wang and Spillane conducted a review of the literature on SST interventions, categorizing it into five groups including social stories, peer-mediated interventions, video modelling, cognitive behavioural training and other [29]. Out of these five categories, Wang and Spillane concluded that only video modelling have demonstrated high-effectiveness. The remaining strategies illustrated promising results, but with moderate effectiveness. Video modelling refers to a technique that involves watching a video that shows a targeted social behaviour, while video self-modelling is a variation of video modelling in which the individual watch a video of himself or herself performing a specifically targeted behaviour. According to Charplot-Christy and Daneshvar, the reason children with ASD attend to video models than real people is the level of anxiety and distress they feel interacting with people in real life [7]. Furthermore, according to Sherer et al. [26] children with autism are often very easily distracted and cannot attend to humans or their environment. If the learning is mediated via an exciting medium, the children are far more likely to dedicate their full attention. Recent research illustrates the potentials of computer simulation as an effective medium for teaching a wide range of skills to individuals diagnosed with ASD [28]. Computer simulation based interventions enable rehearsal of skills in control environments, allowing the individual to work on his or her own pace. This is especially effective for the ASD population given their discomfort with unpredictable situations and interacting with other people. Furthermore, according to several sources [22], [13] multimodal learning interventions can generally create better learning condition by limiting the cognitive load and cognitive overload compared to single modality learning interfaces. Furthermore, teachings that involve more spatial and visual cues are better preserved in young people diagnosed with ASD compared to verbally mediated knowledge [9].

Several studies have examined the effectiveness and feasibility of interactive virtual environments as SST intervention for individuals diagnosed with ASD. Didehbani et al. [10] measured the effect of interaction within a virtual environment using keyboard and mouse to train social skills on thirty children diagnosed with ASD between the age 7-16. The participants completed some true-to-life social scenarios, each designed to emphasize targeted social learning objectives in a variety of contexts such as dealing with bullies, confronting conflicts or bonding with a friend. Three main skills were measured pre-post the experiment: emotion recognition, social attribution, attention, and executive function. The participants showed improvement in all the measured skills. Mitchel et al. [19] examined the effects of an interactive desktop-based virtual cafe to teach social understanding to 6 adolescents diagnosed with ASD. The participants started at the till with a tray containing food and drinks, while they were asked to navigate the cafe and find a place to sit on. Pre-post measurements indicate that participants showed a significant improvement in their social decision making after the virtual environment training sessions. The rapid development of affordable head-mounted displays (HMD) enables development of immersive SST interventions where we can place the learner inside a simulated environment in which he will not be disturbed by external stimuli. As one of the common overlapping syndromes with ASD is attention deficit hyperactivity disorder (ADHD) [18], it’s essential to reduce the number of external factors that can disturb the students during the SST intervention. Due to the novelty of affordable HMD equipment, there have been limited studies on interventions to teach social skills to individuals.
We set out to design an HMD based VR social skills training intervention to be used by the teachers at Valhøj school to teach social skills to their students. The VR social skill training application was developed through an user-centred design approach [1], aimed at identifying the teachers’ current context when performing social training sessions. Three teachers participated in an unstructured interview with the purpose of discussing their current concerns with their students social skills training sessions. All three teachers work with children diagnosed with autism on a daily basis. During the meetings, the teachers described the students’ lack of appropriate play skills, explaining the childrens’ difficulties with basic concepts such as sharing, negotiation, conflict resolution, turn-taking, reciprocity, and manners. These deficits described by the teachers showcased the childrens’ inability to understand and identify the thoughts, feelings, and intentions of others, an ability which is called the theory of mind. A study conducted by Cohen et al. [5] suggested that children diagnosed with ASD have deficits in theory of mind compared to their normal peers as well as peers diagnosed with Downs Syndrom. Teachers at Valhøj school use social stories about sharing as a tool to explain to the children diagnosed with ASD that other people can have different thoughts, goals, and feelings than themselves. According to Ali & Fredrickson [2], social stories can be used to explain what another person might be thinking and why they behave in certain ways in different social situations. However, during the interview, the teachers revealed that it could sometimes be hard for some of the students to understand the feelings and mental state of the child in the social stories, who has been through an uncomfortable play situation. Based on the concerns and current context of the teachers, it was decided to design a VR based social story intervention about playing, sharing and turn taking in a classroom context. To create more empathy and understanding for the characters involved the VR intervention, the child is to experience the VR social stories from a first-person perspective. One of the main requests of the teachers was a social story that takes place in an environment similar to the students’ current classroom. By bridging the gap between the context of the VR social story to a real-world context in which the desired social skills are to be performed, we would create the possibility for a near transfer of learning. According to Arnold et al. [3], when a child diagnosed with ASD learns new behavioural skills in a specific context, the newly gained knowledge often falls short when the individual is presented with a deviation of the social scenario in a different context. An extensive body of research suggests that children diagnosed with ASD have limitations with regards to generalization, which describes the behaviour change in training setting naturally transfers to other settings and context [3]. Stokes & Bear [27] propose a strategy to promote generalization skills in individuals diagnosed with ASD called "Program Common Stimuli". The Program Common Stimuli is a strategy that attempts to include common stimuli across both the training and generalization setting where the social skills will be needed. Therefore, the VR social story will take place in a virtual classroom environment which is designed to look similar to the Valhøj school students’ real classroom (figure 1). During the focus group interview, the teachers also requested the ability to communicate with their students while they are experiencing the VR social story. Enabling a communication channel between the teacher and student during the VR social skills training intervention can enable the teacher to encourage replacement of maladaptive behavior and promote prosocial behavior. According to Gray & Garand [14] social stories should include:

- A specific target behavior of concern
- Help identify an appropriate behavior
- Be written from the childs perspective
- Include pictures or drawing to help child relate to the desire behavior.
- Include a ratio of one directive sentence for every two to five sentences that are describe, perspective or both.

The specific targeted behaviour of concern in this study will be sharing. The teacher will help the child identify the appropriate behaviour by talking to the child during and after the VR intervention via directive, describe or perspective sentences. The VR social story application will be viewed from a first-person perspective and will include 3D visuals designed to look pleasing to a child. The VR intervention was designed and developed using Autodesk Maya and Unity. HTC Vive was chosen due to its room scale tracking as well as its intuitive hand controllers. A computer consisting of an Intel i7 7700k processor, GTX 1080 GPU, and 16GB of DDR4 ram was built for the study. Voices of authors were recorded, and their pitch changed to sound more like a child. An avatar of the teacher was placed in the virtual classroom (figure 2). The teacher could communicate with the child via a microphone. Danish is the main language of the application. The application consisted of 3 scenarios:
The students' age ranged from 9 to 11, and all of them were male, consistent with the gender ratio of 5:1 (male: female) in children diagnosed with ASD [11]. Consent forms were sent to and signed by the children's parents prior to the study. Before the study, the teachers tried the VR social skills training by running a social story session on each other to get comfortable with the application. Due to the small sample size, a Mixed Method Sequential Explanatory Design method was used for the experiment [16]. This method involves the collection and analysis of quantitative data first, followed by qualitative data in two sequential phases within one study. The basis for mixing both quantitative and qualitative data is grounded in that neither the quantitative nor the qualitative methods on their own are sufficient to capture the effects of the intervention. Quantitative data was collected via questionnaires filled out by the teachers in the following order:

- Questionnaire filled out after each social story session.
- Questionnaire filled out after all the social story sessions
- Follow up unstructured interview

### 3.2 Questionnaire after finishing all the VR social skills training sessions

The results of the questionnaire filled out by the teachers after they have conducted all the VR social story sessions can be seen in (table 2).

<table>
<thead>
<tr>
<th>Question</th>
<th>Student one</th>
<th>Student two</th>
<th>Student three</th>
<th>Student four</th>
<th>Student five</th>
</tr>
</thead>
<tbody>
<tr>
<td>The program was good at targeting the behavior of concern</td>
<td>3</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>The student could relate to the social story</td>
<td>3</td>
<td>4</td>
<td>4</td>
<td>5</td>
<td>4</td>
</tr>
<tr>
<td>The student correctly explain the right social behavior</td>
<td>3</td>
<td>3</td>
<td>5</td>
<td>5</td>
<td>5</td>
</tr>
</tbody>
</table>

The first teachers conducted social story session on student one and two while the second teacher conducted social story session on students three, four, and five. There were some technical issues with the sound of the microphone that was implemented to be used to communicate with the students in the virtual environment. Therefore, after the first session with student one, the microphone was not used. The students could hear the teachers voice through the headset, although not as clear as we would like. The teacher rated the three questions on student one, while the rating for the program was good at targeting the behaviour of concern and the students could relate to the social story received a four on the story session with student number two. Student two's explanation after the VR social story session was rated lower on a three. The second teacher rated all his students explanation of what is the right behaviour as high as possible. Student number four was rated five on his ability to relate to the social story. The second teacher rated the rest of the questions with fours.

### 3.3 Follow up unstructured interview

The qualitative part of the study consisted of a semi-structured interview with the two teachers to validate and triangulate the data collected from the questionnaires.
rated five out of five on questions on VR usefulness for rehearsing appropriate social behaviour, VR social story usefulness for more of his students and Three scenarios help the student relate to the characters in the social story. The rest of the questions were rated four by the second teacher.

3.3 Interview results

The interview transcripts were coded using NVivo. Magnitude coding [15] was applied by assigning positive and negative values to comments on the intervention as a tool for the teachers and students’ learning. There was a total of 18 positive comments and eight negative comments. A third category ”future development” was also spotted after coding the interview with five comments.

3.3.1 Positive comments on learning

Both teachers had positive comments on the interventions overall social skills teaching capabilities. One of the teachers mentioned: ”There was a transfer effect from the first scenario to the second and third scenario. I could see that the student approached the avatar in a much polite way in the third scenario”. The second teacher described how the student reacted to being denied when asked to borrow the computer in the third scenario ”At first he got frustrated, but then he realised that this is what happened in the first scenario when an avatar toke his computer without asking”. The teacher also mentioned that ”The students got an ‘aha-experience’ once the avatar took the computer from them without asking”. Some of the positive comments were more related to the student’s motivations when it comes to new technologies. One of the teachers mentioned that ”None of our students with ASD would ever say no to VR. They are not always prepared to try something new unless it rings a bell inside them”. The teachers also mentioned that ”they are already so hype around computer games. They can easily figure out new games, and they are not afraid to experiment and be an active actor in the game. If it, on the other hand, were a conventional social story, they would be more passive.”

Comments such as ”The students were good at following instructions” and ”The students were good at focusing the teacher” show that the teachers felt that they were still able to communicate with students while they were experiencing the VR social story. Furthermore, one of them elaborated the importance of their role in a VR social story intervention ”A teacher is required for such an application. Without us, the student would not be able to understand what is going on since it was us who connected the story together for them and they could ask us questions”. One of the teachers had one positive comment on the usability of the system: ”After trying the application once, I understood how to use it. It’s not rocket science”.

3.3.2 Negative comments on learning

Most of the negative comments on the students’ ability to learn from the VR intervention concerned with the students’ ability to filter out unwanted information. ”One has to narrow down their perception to have their full attention. Even a shadow on the floor can sometimes distract them, or if there is a ’slash’ on the blackboard instead of an ’and’. Even the smallest detail can sometimes get their full attention”. On that note, another teacher added that ”It was nice that the virtual classroom was like their real classroom, but it can end up being a distracting element of the application. The students diagnosed with ASD might notice if there are minor details in the VR classroom that are not exactly the same as their real classroom”. Finally, one of the teachers mentioned: ”Not all of our students are used to looking at faces” when discussing whether the avatars facial expression had any effect on the learning outcome.

The first teacher had a negative comment on the application’s learnability: ”It was important that we conducted a pilot study with the system. Otherwise, it would have been hard for me to use the system”. The teacher further commented that it was hard for him to understand his role when using the system: ”The challenge for me was that I could not understand how to play my role as a teacher in the virtual environment.” He further commented that ”I will need more time with the application to better understand how to be a teacher in it. The students learning is negatively effective due to my lack of personal experience with the system”.

3.3.3 Comments on future development

"Our students can have very different needs so it could be nice if we could design specific cases in VR for each of them. For instance, one of our students is afraid of being photographed”. Another teacher mentioned that: ”One of our students is afraid of crowded situations, so an application that can expose him to crowded scenarios such as the athletic day at the school could be good for him”. Another suggestion was ”We are currently trying to teach our students skills that help them towards independent adulthood. Therefore, it could be nice with a VR experience that can teach them skills such as taking the bus on their own”. The final two comments address needs for social communication training of their students: ”We would love to have a scenario where they could practice keeping a low tone when speaking to someone who seats right next to them”. And: ”...rehearsal of skills such as is it socially acceptable to hug someone you just meet”.

4 DISCUSSION AND CONCLUSION

This exploratory study assessed the feasibility of designing an HMD based VR invention to be used as a tool to teach social skills to children diagnosed with ASD. Three teachers who work with social skills training of children diagnosed with ASD as part of their daily job were involved in the design process. The teachers confirmed that the children they work with lack the theory of mind. They further described social stories as their main tool to teach social skills to their students. The teachers current main mean of communicating social stories are comic strips design to illustrate a variety of right and wrong behaviours. According to the teachers, keeping the children immersed in the comic strips can be a challenge while they are often fully attentive when playing computer games, confirming previous research indicating the ASD populations strong motivation towards electronic media [25]. Based on the data from the teachers, three interactive social scenarios were designed to utilise the main advantage of HMD based VR. Previous studies assessing the effectiveness of virtual environments to train social skills in children diagnosed with ASD have often used desktop solutions [10], [19]. Desktop-based virtual environments can be explored using keyboard, mouse or joysticks while HMD based VR enables the opportunity to look around and explore the virtual environment using the same motoric functions as we use to look around and explore our real-world environment (e.g. turning our head around). Additionally, hardware such as the HTC Vive used for this study offers the possibility to develop virtual environments within which the user can also move around in the virtual environment using the same motoric functions as we use to.

<table>
<thead>
<tr>
<th>Question</th>
<th>Teacher one</th>
<th>Teacher two</th>
</tr>
</thead>
<tbody>
<tr>
<td>Effective in communicating the social story</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>Scenarios help the child relate to the characters in the social story</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>Can be useful for more students in our school</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>Can be used to help identify an appropriate behavior</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>Is useful for rehearsing appropriate social behavior</td>
<td>4</td>
<td>5</td>
</tr>
</tbody>
</table>
move around in our real-world environment (e.g. walking). HMD based VR enables the ability to provide a continuous stream of artificial stimuli that can lead to the perception of ecological and non-synthetic environments that can replicate a variety of social scenarios within which social skills can be thought to children diagnosed with ASD.

Didehbani et al. [10] refer to motion sickness as the main argument against using HMDs as a tool for the social training of children and adolescents diagnosed with ASD. The teachers that participated in this pilot study did not report any of their students having motion sickness during the VR social story sessions. Due to the small size of the study, it cannot be confirmed that the designed VR social skills training intervention isn’t going to induce motion sickness to its users. However, using sensory conflict theory, it can be argued that motion sickness is reduced if the users perception of self-motion is congruent with the user’s vestibular system, proprioception, and visual information as its the case with the designed HMD VR social story intervention [24]. Furthermore, only male students participated in this pilot study. According to [20], the risk of motion sickness in HMD based VR can be greater for female users than male users which is consistent with finding that women are in general more susceptible to motion sickness than men [17]. Finally, research conducted by Newbut et al. [21] showcase that children with ASD are willing to wear HMDs and reported enjoyable experience with high level of presence.

Based on the feedback in this exploratory pilot study, it can be argued that VR can be used as a tool by teachers to teach social skills to children diagnosed with ASD. Teachers comments illustrated that the children understood the social scenario and were able to relate to the feelings of both characters in the story. This is consistent with the main goal of social stories which is to encourage a better understanding of an event and thereby to promote a proper response. In the same way, as with social stories, the VR based social story can be used to encourage replacement of maladaptive behaviour and to promote prosocial behaviour through conversation with the teacher during the sessions. Both teachers commented that the students were good at explaining the social situation during the VR intervention. However, according to the teachers’ comments, the virtual classroom designed to look similar to the students’ real classroom might have been distracting the students. The teachers mentioned that students diagnosed with ASD would notice the differences between the virtual and real classroom, focusing on those differences instead of the social story. Having a teacher avatar in the VR environment might have helped the children not to forget that the teacher is present in the virtual environment with them. However, due to technical errors, the teachers were not able to communicate with the students through a microphone. Luckily the headphones worn by the students were not noise cancelling, and they could still hear the teachers voice.

The designed HMD based VR intervention shows potential in combining the advantages of video modelling, which is described as a motivating SST intervention for children [7], with advantages of social stories ability to promote understanding of a social scenario [2]. Future research should measure childrens motivation for learning social skills in an HMD based VR intervention. Furthermore, future comparative studies should evaluate the HMD based VR social story intervention compared to the conventional social story interventions.

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