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Training Social Skills of Children with ASD Through Social Virtual Robot

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Abstract

In this paper, the researchers presenting an ongoing study that aims to evaluate the effectiveness of combing Virtual Reality (VR) and social robot as a novel approach to enhance the social skills of children with autism spectrum disorders (ASD). Using Unity 3D, a desktop Virtual environment that employs a virtual robot to interact with the participants through social skill training programme has been developed. 15 children with ASD are participating in the study to evaluate the effectiveness of the developed tool. The initial results show improvement in the skills of the participants.

Index Terms: Virtual reality—Social robot—Social skill training programme—Autism spectrum disorder

1 Introduction

Virtual Environments (VEs) are a computer-generated artificial environment that makes the user feel they are part of these environments. There are two types of Virtual Reality (VR): Immersive VR (see Fig.1), and Regular "Non-Immersive" VR (see Fig.2). In the Immersive VR, the user completely surrounded by the virtual environment via head-mounted displays (HMDs) or projection systems (CAVE). While regular "Non-Immersive" VR is a type of VR that uses computer monitors or TVs as displays, such as video games.

Recent years have seen an increase in the number of applications and systems that apply VR to enhance learning and training methodologies. VE and Virtual Characters (VCs) become the tool for training and rehabilitation of children with Autism Spectrum Disorders (ASD). According to [22], VEs and VCs can enhance the social skills of children with ASD by simulating real scenarios from daily life which will help them practice social skills. Children with ASD are attracted to systems that contain animations and sounds which help to reduce their stress and give them a sense of safety. Using VR as a training tool for children with ASD has several advantages such as practicing in a safe environment, gradually increase of the level of complexity, decreasing stress, simulating realistic scenarios, providing immediate feedback and the repetition of tasks [4, 6, 7, 22].

ASD is a neurodevelopmental disorder that appears at an early stage and affects the child development [20, 27]. Children with ASD characterised by challenges with social skills, repetitive behaviours, speech and nonverbal communication. According to the centres for disease control and prevention (CDC), 1 in 54 children has been identified with ASD [9].

2 Social Skills Interventions for Children with ASD

Social skills training (SST) programmes are one of the widely uses approaches for teaching and training social skills to children with ASD [25]. The aim of SST programmes is teaching children with ASD the necessary skills to communicate more effectively with others. Social skills training programmes based on dividing the

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Figure 1: Immersive VR [28]

Figure 2: Non-Immersive VR [26]

complex interactions into simple tasks (such as maintaining eye contact or responding with appropriate answers) towards achievable steps. Peer mentoring, social skills group, video-modelling, social stories, picture exchange communication system, applied behaviour analysis, and occupational therapy are types of social skills training interventions for children with ASD.

Although SST interventions are effective, they have some limitations. Most of the interventions have been developed for a broader population of ASD, very few SST interventions for children with high-functioning ASD. Social skills training sessions are not available for all children with ASD due to the high cost of these sessions and the shortage of trained therapists. Lack of generalisation is a major limitation in SST interventions as the majority of studies don't include methods for measuring the generalisation of the learned skills. In this capacity, a wide range of studies have investigated the potential use of assistive technology. Assistive technology can offer a means to practice social skills through an inexpensive, less time-consuming and more scalable option. Assistive technology has been implemented in VR and robots to support children with ASD in their life.

2.1 Virtual environments for ASD Training

Wide range of studies has been conducted to evaluate the effectiveness of virtual environments in improving the social life of children with ASD.

A virtual pet shop has been developed by [29] for practicing conversation skills for children with ASD. [10] have designed a 3D environment to enhance the emotion recognition and expression of three adolescents diagnosed with ASD. Another study by [31] to teach children with ASD emotion recognition in a 3D environment through a serious game "JeStiMulE". After training sessions with JeStiMilE, participants were more accurate in emotion recognition tasks. A serious game "Pico's Adventure" in a form of virtual environment has been designed by [18] to promote social interaction in children with ASD. The game utilised an alien avatar "Pico" to interact with the child. The findings of this study show the acceptance of the game design to the participants. The study hasn't assessed the child's behaviours in the baseline sessions; thus, the researchers couldn't report any changes regarding the target skills. Additionally, they couldn't evaluate the effectiveness of the proposed game in generalising the target skills to the real world. [2] designed virtual 3D human character in a serious game "LIFEisGAME" to teach children with ASD to recognise facial expressions. The 3D characters have a child-like appearance.The results suggested that children with ASD prefer different types of avatars such as animals or aliens, although

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Figure 3: Social robots for ASD training

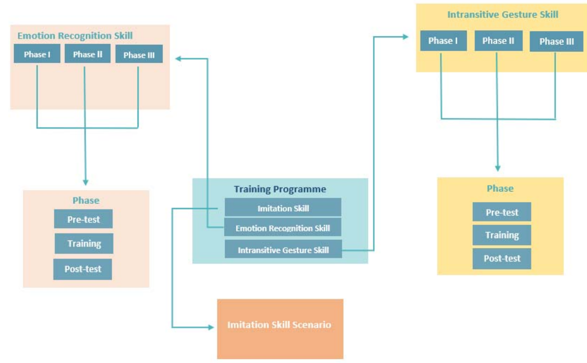

Figure 4: The social skill training programme

the avatars need to be in a cartoon shape. A desktop virtual environment ”ECHOES” has been developed by [3] to allow children with ASD to understand and explore interaction skills. The VE has been utilised a child-liked appearance virtual character ”Paul” to interact with the children. As a result of this trial experiment, the researchers did affirm that the virtual character was successful in engaging the participants. However, the study doesn’t report any changes in the participants’ behaviours or skills due to the short training session.

Although the promising results of employing virtual environments in ASD training, the generalisation of the acquired skills in such environments to the real world remains an open question. Most of the studies don’t conduct follow-up sessions to assess whether the children transferred the target behaviours and skills learnt in the intervention to daily life. The high cost of VR equipment, its heaviness, discomfort and the lack of general availability are potential barriers to widespread of the immersive VR interventions. Thus, desktop-based VE is preferred over the immersive VR.

2.2 Socially Assistive Robots for ASD Training

In the last years, socially assistive robots have been widely used in autism intervention. Social robots that have been used for training children with ASD have different appearances and characteristics (see Fig. 3). Previous research has shown that social robots have been used as assisting technology in many areas of autism research. In particular, they have been used to teach social skills [8, 13, 16]. Studies of robot-assisted interventions with children with ASD report that the robot has a positive effect on the child’s engagement, joint attention, imitation and communication [11,30]. In return the use of robots can enhance the learning outcome, as engagement considered to be an important prerequisite for learning, where higher engagement results in more opportunities for social skill learning [16,30].

A case study has been carried out by [35] using KASPAR robot to evaluate the interaction between autistic children and the robot. Learning emotions, greeting skills, and imitation skills are the targeted social skills of this study. After 10 sessions of greeting skill task, the children start using a greeting in their daily life. They also got engaged in learning emotions and imitation tasks. [12] conducted a study using QTRobot to enhance emotion ability in ASD children emotion. 40 ASD children participated in this study who are aged between 5 to 12 years old. Another study by [21] using the NAO robot to teach ASD children how to express emotions using body language. The robot demonstrates emotions using body postures and colours as it does not have facial expressions.

Despite that, children with ASD are more responsive to feedback given by social robots than by a human, the accessibility of robot interventions is limited. Robot-based interventions for children with ASD are difficult for many families to access due to high cost and the lack of trained operators to control the robot.

3 Contribution

In this paper, we present our contribution of developing a tool that addresses the limitation of VR and social robots interventions. The developed tool is a novel approach of combining VR with the social robot to train imitation, emotion recognition and intransitive gestures of children with high-functioning ASD (HFA). To overcome the high cost of VR equipment and the robot platforms and the constrained geographic availability of social robots, the developed environment is a desktop-based VE which employs a virtual robot (see Fig.5), that interacts with the child through training social skill programme. The training programme is adapted and modified from several studies [13, 16, 21, 32] that utilised physical robots (NAO, QTrobot and Zeno) to train children with ASD. The aim is to evaluate the effectiveness of using virtual robot in enhancing the social skills of children with ASD and compare between the results achieved during the interaction with virtual robot and those achieved during the interaction with physical robots that have been used in the state-of-the-art. The developed tool uses by parents and teachers either at home or at school to ensure their involvement in the intervention and follow up sessions. As the evaluation process is conducting in Egypt and The United Kingdom, an Arabic version of the tool has been developed.

4 Social Skill Training Programme

The developed social skill training programme targets three social skills: imitation, emotion recognition and intransitive gestures (see Fig. 4). The training programme consists of different scenarios that aim to enhance the target skills of children with ASD. There are three actors in the interaction scenarios: a child, a parent/ teacher, and the virtual robot. Each actor assigned for a specific role in the scenario such as an initiator (The virtual robot who models the target behaviour), a responder (The child who imitates the actor’s action and responds to the robot’s questions) and an observer or a moderator (The teacher or the parent who controls the movement of the virtual robot, observes the interaction between the child and the robot and helps the child through out the session if asked for help. For example, if the child can not read, the observer/moderator reads the options for her/him). These three actors establish a triadic interaction. That type of interaction happens between the child, robot and the teacher/ parent.

The social skill training programme used in this game is informed by established work and existing practices have been done using physical robots and proven to be beneficial in enhancing the social skills of children with ASD [13,16,21,32].

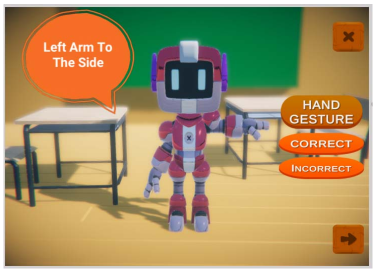

Figure 5: The imitation scenario

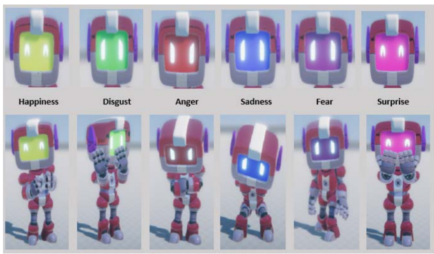

Figure 6: Jammo robot expresses emotions

4.1 Imitation Skill

Imitation skills are an important element in the child's social learning process to develop new behaviour, they need to mimic. To develop a new behaviour or skill, children need to mimic. Improvement in the imitation skills of children with ASD is connected to the improvement of their play skills [17, 34].

The imitation skill scenario is at the beginning of each session. All the sessions start with the virtual robot greeting the child and introducing the game to the child by saying "Now we are going to play an imitation game. I am going to do something and you are going to do the same, Let's go". The virtual robot guides the child to imitate its action by language and body movement (see Fig. 5). The virtual robot has been programmed to animate 9 different hand gestures such as left hand up, both hands to the side, etc. The moderator clicks 'Hand Gesture' button to instruct the robot to animate a hand gesture. The robot animates 9 hand gestures one after another in a randomised order and the child imitates each hand gesture. The moderator judges the child's action.

4.2 Emotion Recognition Skill

Emotion recognition is an important contributor in social communication [5, 19]. Children with ASD characterised by deficits in their emotion recognition skills. Improving the emotion ability of children with ASD is extremely crucial for their development. The emotion recognition training programme consists of 3 phases, each phase contains a pre-test, four training sessions (with two sessions per week), an immediate post-test and a follow-up post-test after 2 weeks. Jammo robot has been programmed to demonstrate the six basic emotions introduced by [15]; Happiness (yellow), Sadness (blue), Fear (purple), Anger (red), Disgust (green), and Surprise (pink). As the virtual robot does not have facial expressions, it expresses emotions using body postures, colours and eye shapes (see Fig.6).

4.2.1 Phase I

Phase I aims for recognising the basic six emotions. The virtual robot greeted the child and gave instructions for the pre-test. The purpose of the pre-test was to examine whether the child was able to

Figure 7: Phase I

recognise the six emotions expressed by the virtual robot through body movements, change the colour of the face, and change eye shape. The moderator pressed the 'play emotion' button to instruct the robot to produce an emotion one at a time in a randomised order and asking the child "what is the name of this emotion?". The child should choose one of the three options that appear on separate buttons on the screen. The robot provides feedback based on the child's answer. The pre-test completed after the six emotions had been covered, and there was a score to count the child's correct answers. Then the child proceeded to the training scenario. In the training scenario, the child watched the robot express the six emotions one at a time in a randomised order while explaining the name of the emotion and when we feel it. Each of the emotions has been associated with a cartoon character [14] to grab the child's attention and help in the learning process (see Fig.7). Immediately after completing the four training sessions, the child proceeded to the first post-test which is identical to the pre-test. Two weeks after the training, the child received the follow-up test. The scores of the pre-test, post-test and follow-up test have been compared.

4.2.2 Phase II

Phase II aims for expressing emotions through imitation. In the pre-test asked the child to express an emotion one at a time in a randomised order by saying for example "what is the expression for happy?". The word "Happy" appeared on a bubble on the screen (see Fig. 8). The moderator judged the accuracy of the child's expressed emotion and either pressed 'Correct' or 'Incorrect' button. There was a score to record the child's correct answers. Then the child proceeded to the training, where the virtual robot expressed the six emotion one at a time in a randomised order. Each time the child asked to imitate the robot's expressed emotion. After finishing the four training sessions, the child took the post-test, which is identical to the pre-test. After two weeks, the child took the follow-up post-test. The scores of the three tests were compared.

4.2.3 Phase III

Phase III aims for recognising and expressing emotion from social context. In the pre-test, the child asked to recognise the appropriate emotion from the social story. The virtual robot narrates a story where it is the main character and asked the child about the appropriate emotion for this story by saying "How should I feel?". The child chose one of the three options that appear on separate buttons on the screen. An example of the stories: "When I was sleeping, I heard something moving in my closet, how should I feel?". The child proceeded to the training immediately after completing the pre-test. In the training, the virtual robot narrates the same stories as the

Figure 8: Phase II

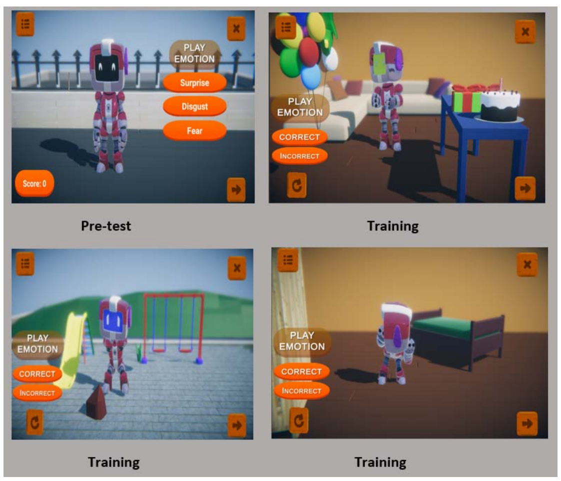

Figure 9: Phase III

pre-test while demonstrating and saying the appropriate emotion for each story. Each time the child asked to imitate the robot's emotion. Different environments have been designed taking into account the plot of each story (see Fig.9).

The procedure of the post-test and the follow-up test is the same as the pre-test, except the post-tests have different stories. For example: "When I was watching the television, I saw a spider on the wall, how should I feel?". All the scores in Phase III were compared.

4.3 Intransitive Gesture Skill

Gestures are a prerequisite for the development of languages and also an early indication of communication skills [23, 24]. Children with ASD have delayed development of gesture comprehension and production in comparison to their typical development peers of the same age. These impairments result to delay in language development in children with ASD [23, 33].

The intransitive gesture training programme has the same protocol as the previously mentioned emotion recognition training programme. The virtual robot has been programmed to demonstrate 11 gestures. The gestures are hello, good job, look at this, yes, stop, where, me, awesome, come, hungry, and not allowed (see Fig. 10). The aim of the intransitive gesture training programme is training the children to recognise, imitate gestures and produce them in an

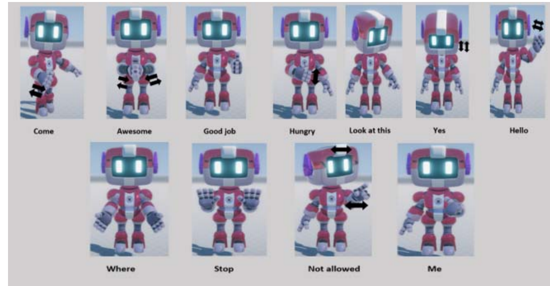

Figure 10: Intransitive gestures produced by the virtual robot

appropriate social context. Phase I aims for gesture recognition, phase II aims for gesture production through imitation, and phase III targets gesture recognition and production through social stories.

5 Participants

8 typically development children with ASD aged 6 to 12 years participated in the preliminary evaluation (6 girls and 2 boys; mean age 9.25 years, standard deviation 2.10 SD). In the meanwhile, 15 children with ASD aged 4 to 12 years are participating in this study as the evaluation process is still ongoing (10 boys and 5 girls; mean age 7.4 years, standard deviation 2.7 SD). Non-ASD Children only participated in the preliminary evaluation and did not participate in the intervention sessions.

This study has been approved by the University of Greenwich Research Ethics Committee. Before starting the intervention sessions, the parents of the participants have been provided with the information sheet that explains the nature of the study, then they have been asked to sign the consent form. The length of the intervention is for approximately three months. The participants are receiving 2 sessions per week. Each session lasts for 20 minutes, but sometimes it depends on the child progress and attention. During the three months of the intervention, the participants are receiving behavioural management therapy at their schools and centres. At the beginning of the intervention, the parents of the participants asked to fill out questionnaires to assess the level of the social skills of the participants. At the end of the three months, the parents will be asked to complete the questionnaires again to evaluate the effectiveness of the developed tool in enhancing the target skills of the participants.

6 Experimental Set-up

Due to the current situation (Covid-19) and the closure of the schools and specialised centres, the evaluation process is conducting onsite and online. An online version of the tool has been developed and launched on a website to be available for wider group (visit the website here [1]). Thus, parents can use it with their children at home. The website contains a detailed video for parents to instruct them on how to download and run the tool. Along with the tool, there are questionnaires and observation sheet for the parents to complete pre and post the intervention. The parent is the controller who chooses the scenario, navigate from one scene to another and help the child and the observer who record the child's skills and behaviours during the interaction with the tool in the observation sheet. To set up the environment at home, the parents only need a laptop (computer) to run the tool.

The on-site evaluation is conducting at specialised centres in Egypt. Each participant experiences the tool individually. The teacher role is controlling the tool by choosing the scenarios and assist the child throughout the session if asked for help. The researcher plays an observer role. The environment set-up consists of the laptop, teacher, participant and the researcher (see Fig. 11).

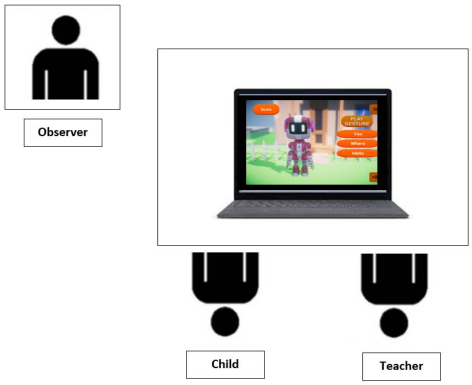

Figure 11: On-site setup

Table 1: List of the 11 gestures producing by Jammo robot and their consistency rate based on measurements of non-ASD children

Gesture	Consistency rate
Hello	100 %
Yes	100 %
Where	75%
Good Job	100%
Stop	100%
Look at this	75%
Me	100%
Awesome	100%
Come	87%
Hungry	87%
Not allowed	100%

7 Results

To ensure that the gestures produced by the Jammo robot in the intransitive gestures training scenarios could be recognised by the participants with ASD, the typical development non-ASD participants were asked to identify the meaning of the gestures demonstrated by the robot in the gesture recognition scenario (phase I, pre-test). The results show that all the 11 gestures had consistency rates of 75% or above which indicate that the gestures produced by the virtual robot are recognisable (see Table1).

The evaluation process with the participants with ASD is still ongoing. The participants have completed Phase I and Phase II of the emotion recognition training programme. Figure 12 shows the mean number of times the children answered correctly in phase I and Phase II of the emotion recognition training programme. we found a significant increase in the emotion recognition ability of the participants after receiving the 4 training sessions of Phase I. Additionally, the results showed improvement in the child's emotion expression ability. After receiving the training sessions of phase II of the emotion recognition training programme, the participants were able to express the basic six emotions.

As a result of phase I of the emotion recognition training programme, some the emotions expressed by the virtual robot were easier for the participants to recognise than others (see Fig.13). Surprise and disgust were difficult for the participants to recognise due to the lack of the facial expressions of the virtual robot. It was hard to reflect these two emotions without the use of the mouth and eyebrows.

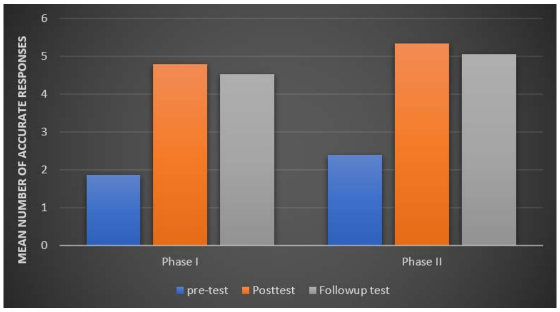

Figure 12: Mean number of accurate trials in the pretests, posttests and followup tests in the two phases

Figure 13: Percentage of the recognised emotions produced by the virtual robot

8 Conclusion

This paper presented an ongoing study that aims to evaluate the effectiveness of a new approach to enhance the social skills of children with ASD. The novel approach is a combination of two assistive technologies: virtual reality and social robots in association with established social skill training programme. The developed environment is a desktop virtual environment that employs a virtual robot to interact with the child through a social skill training programme. The virtual social robot implementation has resulted in a lower cost and more readily available system that can be downloaded and used by parents and teachers with internet access. The developed social skill training programme is a replication of several training programmes that have been used by the state of the art. The evaluation process is still ongoing and conducted in Egypt and The United Kingdom. Thus, the tool has been developed in two languages Arabic and English to be easier for the participants and parents to use. Four to 12-year-old children with ASD are participating in this study. At this stage, it is too early to make an analysis or any statement regarding the generalisation of the acquired skills to real life, further experimentation will indicate that. Although, the initial results show improvement in the participants' emotion recognition and expression ability.

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