Fostering Social Communication for Children with Autism through Augmented Reality Toys

MHL Abdullah[1*], BT Tong[1], NFN Mohamad Daud[1], MH Zakaria[1]

1. Centre for Advanced Computing Technology (C-ACT), Fakulti Teknologi Maklumat dan Komunikasi Universiti Teknikal Malaysia Melaka (UTeM), 76100 Durian Tunggal, Melaka, Malaysia

ABSTRACT

Purpose: *The fifth edition of the Diagnostic and Statistical Manual of Mental Disorders (DSM-5) classified autism spectrum disorder (ASD) as a neurodevelopmental disorder characterised by difficulties with socialisation and communication, and with restricted interests and repetitive behaviour. The wide range of symptom types and severity of the disorder in children with ASD can range from the need for support to the need for substantial support, and sometimes even very substantial support. This paper examines an augmented reality toy application, AR Toys, which supports social communication of children with ASD, and reports on how the application was used in school classrooms.*

Method: *AR Toys was evaluated by seven children in an Autism Centre in Melaka, Malaysia. The analysis focused entirely on observation of the interactions between children and teachers at the school.*

Results: *It was found that AR Toys were able to: (1) motivate children with ASD on adaptive language; (2) model expressive language to identify a child's emotion; and (3) promote pretend play on learning emotion in classroom activities. This gives children with ASD more opportunities to communicate among peers and interact with teachers at school.*

Conclusion: *Human Computer Interaction (HCI) research using AR technologies shows positive feedback in supporting children with ASD in recognising emotions that facilitate their social communication development, leading to better understanding, communication and engagement between teachers and children.*

Key words: *augmented reality, Autism Spectrum Disorder, social communication, AR Toys*

* **Corresponding Author:** MHL Abdullah, Centre for Advanced Computing Technology (C-ACT), Fakulti Teknologi Maklumat dan Komunikasi Universiti Teknikal Malaysia Melaka (UTeM), 76100 Durian Tunggal, Melaka, Malaysia. Email: haziq@utem.edu.my

INTRODUCTION

Toys are a child's "best friend". Children can give free rein to their imagination while playing with toys. A previous study (Bremner et al, 2019) found that through pretend play, children are able to communicate and express their emotions in a variety of ways, including through facial expression, body language, and expressive language. However, children with ASD usually have defects in playfulness (Zarei et al, 2022) as social communication is a dynamic process that involves the sharing of information in an interpersonal setting (Wieckowski & White, 2017). Thus, virtual toys are able to support children's play by enabling their imaginative play to facilitate them in playful activities with others, regulate their emotional arousal, and possess the necessary skills to initiate interactions and communication with others (Mispa et al, 2016). Furthermore, augmented reality (AR) technology seamlessly merges the real and virtual by overlaying computer-generated virtual graphics on a live direct or indirect real-world environment in real time (Lee, 2012). The technology allows users to interact with the digital content and the actual world. Augmented reality toys enable users to interact with AR content and start their pretend play with the toys. With the assistance of media content such as 3D animation, soundtracks and graphics, children with ASD can experience and recognise facial expressions and body language.

Research in human-computer interaction (HCI) has investigated approaches to support the development of children with ASD. These approaches have often focused on technology that tends to be relatively complex and expensive, such as robotics and virtual reality (Abdullah & Brereton, 2015). In a similar vein, avatar technology to support the development of children with ASD has also received significant attention (Ying et al, 2016). In fact, the personalised avatar integrated into technology has also demonstrated its ability to increase learning content engagement and facilitate the educational process for children with ASD (Ying et al, 2016). At the same time, children can convey their feelings during playtime with the AR toys. This study specifically reports how AR can assist children with ASD in supporting their social communication and interaction by expressing their emotions correctly.

Related Work

Immersive technology such as virtual reality and augmented reality are widely used to support children with autism spectrum disorder. Lahiri et al (2011) and Bellani et al (2011) demonstrated that virtual reality (VR) technologies are a

promising intervention to support individuals with ASD. Both studies identified the potential of VR technology to provide better support in socialisation for individuals with ASD. Lahiri et al (2011) demonstrated that VR technology has the potential to promote social interaction among adolescents with autism. Bellani et al (2011) supported that the use of VR technology enhances the social behaviour of those children. In a similar vein, Mora-Guiard et al (2016) showed that VR technology is a useful tool to foster social interaction and collaboration behaviours for children with ASD. More recently, Bozgeyikli et al (2016) found that immersive virtual environments provided an effective alternative training tool for improving vocational skills (e.g., cleaning, loading the back of a truck, money management, shelving, environmental awareness, and social skills) for individuals with ASD.

Another technology used to support children with ASD in their social interactions is augmented reality (AR) technology. Escobedo et al (2012) stated that AR technology has the potential to integrate children with ASD and typically developing children, enabling them to practise social interaction in their daily lives. Mobile and AR technologies offer significant potential use of newly acquired social interaction skills.

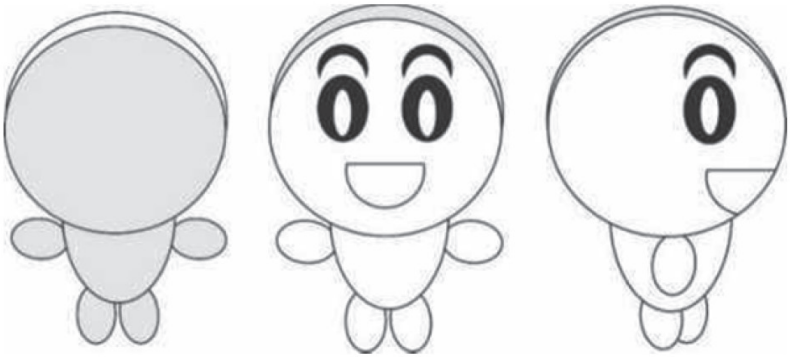
A limitation of using VR technology in helping children with autism spectrum disorder lies in managing the use of individualised interventions, because children with ASD have deficits in viewing patterns during social activities, according to Lahiri et al (2011). Similarly, Parés et al (2005) confirmed that individuals with ASD require technological intervention that is personalised to their needs and abilities for the intervention to be successful. Lahiri et al (2011) stated that another challenge for children with low-functioning ASD is that technology with the capacity for a dynamic supporting role is required to allow the highest interactivity levels between children and the virtual avatars in VR technology. The study by Bellani et al (2011) found that VR technology was able to help caretakers and educators to enhance social behaviours among children with ASD. They pointed out that the new skills that the children acquire in a VR environment need to be transferred to their daily lives to help them maintain their social skills in the real world. Similarly, Boyd et al (2017) argued that the social skills developed in a virtual world among children with ASD need to be maintained in the physical world.

Augmented Reality Application (AR Toys Application)

The AR Toys application was co-designed with the study's research team and special education teachers who teach children with autism. The research team conducted a contextual interview and discussion with teachers in the National Autism Society of Malaysia (NASOM Melaka). The research inquiry focused on understanding how to support social communication among children with ASD in the classroom, using five basic emotions (happy, sad, angry, scared, and disgust) which have always been taught in the classroom. The contextual interview and discussion with the special education teachers led to the designing process of the AR Toys application. In order to fulfil the requirement in supporting children's development in social communication, the details of the AR Toys application's design concept development was identified and discussed with the special education teachers at NASOM.

A low fidelity prototype of the AR Toys character design was presented to the special education teachers for approval on the AR application content, as depicted in Figure 1.

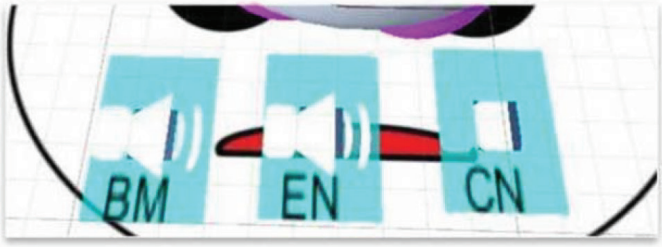
Figure 1: Low Fidelity Prototype of AR Toys Design Concept



After the special education teachers' approval, the research team developed a three-dimensional (3D) AR Toys application (see Figure 2) with three languages, namely Malay (BM), English (EN), and Chinese (CN), to cater to the social communication development for children with ASD by learning five basic emotions in the classroom (see Figure 3).

Figure 2: 3D AR Toys Application represents Five Basic Emotions (happy, sad, angry, scared and disgust)

Figure 3: AR Toys Application available in Three Languages (Malay, English, and Chinese)



Objective

This research study aims to examine an augmented reality toy application, AR Toys in supporting social communication of children with ASD at school.

The study explores augmented reality (AR) technology as an assistive tool to present computer-based elements which are specific for children with ASD. The study focuses on the design of AR toys in keeping with the style of Malaysian toys to ensure their attractiveness and familiarity among children in Malaysia.

METHOD

Study Sample

A total of seven participants, consisting of six males and one female, were involved in the trial. The children were of different ages and had differing severity of ASD. They were selected from the centre by the special education teachers. They were tested mainly on their level of understanding towards the AR Toys application

and capability of using the application. The children's interactions and reactions were observed throughout the trial. The researchers were assisted by two special education teachers.

Data Collection and Analysis

The testing was conducted in a classroom with this small group of children with ASD. During the trial, the children with ASD used the AR Toys application to learn the five basic emotions to facilitate their social communication. The participants' interactions with the application were observed and recorded. The data was collected and analysed using manual coding. Then, an interview was conducted with the special education teachers to confirm and refine the identified themes from the findings.

The thematic analysis of the AR Toys application used in the classroom identified three additional themes in relation to the teachers and children's interactions. The emerging themes from the analysis are discussed in the Results section.

Ethics Approval

The Human Research Ethics Committee of Universiti Teknikal Malaysia Melaka approved the study protocol. Prior to the trial, written consent to involve each participant was obtained from the coordinator of the National Autism Society of Malaysia (NASOM Melaka).

RESULTS and DISCUSSION

The observations in the classroom revealed that the participants spent a significant amount of time playing with the AR Toys application, especially with the happy emotion on which they spent 38% of the time. Additionally, during their interactions most participants preferred to use the AR Toys application in the Malay (BM) language as compared to English (EN) or Chinese (CN).

Theme 1: AR Toys Application can Motivate Children with ASD on Adaptive Language

This study found that the AR Toys application is able to motivate children with ASD on adaptive language. The AR Toys application is available in three languages, namely Malay (BM), English (EN) and Chinese (CN). The observation in the classroom found that most of the participants were able to complete the task

using the AR Toys application to learn five basic emotions including expression and reaction. Two participants tried to imitate the language of the voiceover. The teacher mentioned in the interview that the application is useful for these children at school, particularly to foster adaptive language.

> *"…using the native language in the AR Toys application, similar with what the NASOM centre (BM, EN) teaches in the classroom, is a good way to assist children to practise conveying language and communication skills"* (Teacher's comment).

Based on the classroom observation, this study found that a majority of the participants selected BM as their medium of language preference. CN attained the lowest frequency because it is not the native language in the centre and in the children's families. Figure 4 shows a participant trying to imitate the application.

Figure 4: Participant imitating the Application

One of the participants was yelling while interacting with the AR Toys application and was unable to cooperate throughout the whole trial session. Thus, there is a limitation when designing and developing an application for autism, especially in the audio selection during the design process (see Figure 5). The teacher also explained this during the interview session.

> *"Although languages with audio voiceover are good, some of participants are sensitive in auditory sense, so they are unable to interact with the application because it will affect their auditory system"* (Teacher's explanation).

Figure 5: A Participant covering his ears when playing the AR Toys Application

This finding is supported by the study of Bellini (2009), which demonstrated that using adaptive language is suitable for children with ASD to be able to recognise and express their emotions correctly in social communication and interaction skills. In another study, a technology-based intervention became a useful tool to facilitate teachers in building a foundation for communication and language skills among children with ASD, as well as model a language that identifies with children's interests (Abdullah & Brereton, 2017). Clearly, the findings of the present study indicated that the AR Toys application which integrates with native languages is able to assist and motivate children with ASD in their social communication. In addition, this also facilitates teachers' efforts to foster communication skills in the child in the context of daily activities.

Theme 2: AR Toys Application can model Expressive Language to identify Child's Emotion

The study suggests that the AR Toys application is able to model expressive language to identify children's emotions. In this study, during the trial session most of the participants expressed the happy emotion when interacting with the AR Toys application. In addition, the study found that no participant felt sad or disgusted during the trial session. When interacting with the AR Toys application, a total of five out of seven participants first chose to interact with the happy emotion icon, while one participant chose the fear emotion icon and another chose the angry emotion icon. Subsequently, the findings indicated that six participants (85%) expressed happy emotions during the trial session. The teacher assisted the children with ASD to recognise and understand the five basic emotions when using the AR Toys application, and one child yelled 'Yeah'

after he successfully recognised the correct emotions the teacher had asked. The 'Yeah' also indicated one of the child's ways of conveying happiness. Another child clapped his hands and smiled to demonstrate the happy emotion when the teacher asked how to express happiness. Figure 6 shows the participant smiling when interacting with the AR Toys application.

Figure 6: Participant smiling when playing with the AR Toys Application

In an interview, one of the special education teachers discussed the impact of the AR Toys application on children's social emotional development.

"Yes, I agree that the contents are sensitive and interactive. Children are able to recognise and react to the emotions when using AR Toys application" (Teacher's comment).

This finding is supported by Tan et al (2019) who concede that the use of an avatar is able to encourage children with ASD to express their feelings when interacting with technology-based interventions. Additionally, Hughes et al (2016) emphasised that using an interactive and realistic avatar is able to improve eye gazing, facial expressions, and emotions among children with ASD. Hence, the findings of the current study indicated that the AR Toys application is able to model expressive language to identify the child's emotion in the classroom activity.

Theme 3: AR Toys Application can promote Pretend Play in learning Emotions for Classroom Activities

Based on the observation in the classroom, the study also identified that the AR toys application is able to promote pretend play in learning emotions for classroom activities. The teachers conducted a simple quiz (question and answer activity) for the children with ASD during the trial session. The teachers posed questions to the children about the emotion involved by giving a scenario and story, so that the children could guess the correct emotion for each scenario. Below is a conversation that occurred during the question and answer activity.

Teacher: *"Can you tell me what the face is?"* (Point to happy face)

Child: *"Happy".*

Figure 7 shows a child participating in pretend play with the AR Toys application, assisted by the teacher. In this study, the findings showed that four out of seven participants were interested in using the AR Toys application and tried to interact with it more than once. In the interview, one of the teachers commented on how the AR Toys application is able to promote pretend play.

"I am surprised that some of the children had pretend play with AR Toys, although they play with it alone, but it helps children to train their brain in generating ideas while pretend play" (Teacher's comment).

Figure 7: Participant in pretend play with AR Toys Application, assisted by the Teacher

This finding is supported by the study of Barton et al (2012) that demonstrated how pretend play using technology is important for children with ASD to motivate

them in their learning process and development skills. By adopting the technology, the researcher also found that children with ASD are able to play imaginatively and creatively develop stories utilising the virtual toy's objects (Mispa et al, 2016). Thus, the findings of the present study were that the AR Toys application is able to promote pretend play in learning emotions for classroom activities.

CONCLUSION

The study findings suggest that the AR Toys application benefits children with autism spectrum disorder and special education teachers because this application is capable of assisting the children in their social communication skills. Often, the teachers used the AR Toys application as an auxiliary tool to educate children regarding the five basic emotions. The AR Toys application was an assistive tool for children with ASD as it provided them good experience and exposure. In fact, the children showed positive engagement when interacting with the AR Toys application, as they were able to talk, imitate, and pretend play. Hence, this study supports social communication development among children with ASD in classrooms. The study concludes that Human Computer Interaction (HCI) research can support children with ASD by using AR technologies to help social communication, leading to better communication and engagement between teachers and children. In the next stage, this study would like to conduct another trial at a different autism centre, with a bigger group of participants, to confirm the effectiveness of the AR Toys application in facilitating social communication among children with ASD.

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