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Effectiveness of AutistAR to enhance communication and social skills among children with autism

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ABSTRACT

Individuals diagnosed with autism spectrum disorder (ASD) may have serious fundamental deficits in communication, social, inventiveness, and constructive skills. In the age of technology, children with disabilities frequently employ assistive technologies to aid in their learning and support the rehabilitation process, particularly for autism. Individuals with ASD require technology-based tools such as software or applications that could assist them with communication, language, organizing skills, and information processing. This research developed an augmented reality (AR) application integrating picture exchange communication systems (PECS) to aid children's communication and social skills. A single-case experimental design (SCED) method was used to analyze the features and effectiveness of AutistAR. The study included a sample of two individuals diagnosed with ASD, characterized by restricted communication and social abilities. The result revealed that there was an improvement in overall communication and social skills in both participants. The ramification of the findings is further explored.

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1. INTRODUCTION

Autism spectrum disorder (ASD) is a neurodevelopmental condition marked by impairments in social communication and the occurrence of limited interests and repetitive behaviors [1]. The term "spectrum" is commonly used concerning autism, as it signifies that ASD exhibits various manifestations due to the varying degrees of severity observed in individuals affected by the disorder. Asperger's and pervasive developmental disorders are encompassed within the broader category of ASD [2].

The language development and conversational abilities of individuals with autism may be delayed to varying degrees, depending on the severity of the disorder [3]. Communication difficulties can encompass the recurrent utilization of terms derived from media sources and a restricted capacity for imagination. Social engagement poses a prevalent challenge for individuals diagnosed with ASD. Individuals may experience irritation, worry, and adversity in establishing and maintaining interpersonal relationships [4]. Individuals often have a poor comprehension of gestures and facial expressions, which can result in social and emotional responsiveness [5].

According to Funabiki and Shiwa [6], a significant number of children diagnosed with ASD exhibit superior visual memory capabilities in comparison to their aural memory. This tendency can be attributed to the prevalent use of visual aids, such as image cards or illustrations, which are commonly employed to facilitate their everyday activities. Therefore, individuals diagnosed with ASD are commonly acknowledged to possess heightened visual processing capabilities [7]. According to Aldred *et al*. [8], there is a suggestion that employing visual strategies in media can enhance communication skills in children diagnosed with autism. As reported by National Institute of Mental Health [9], children diagnosed with autism tend to engage in repetitive patterns of behavior, which may challenge their ability to connect with others effectively. Therefore, digital devices allow an escape to these children, where predictable outcomes allow them to perform at their own pace [10].

Technology is now increasingly used in many educational contexts as assistive technologies and instruments to increase children's motivation for learning [11]. Regardless of a child's speaking capacity, assistive technology can help improve communication among children with autism. Numerous studies have endorsed using contemporary technologies to teach skills to people with ASD [12]. Using sensors, augmented reality (AR), virtual reality, virtual agents, geolocation, and Kinect are some intriguing examples of the new technical techniques [13].

As children with autism struggle to communicate and lack social skills, augmented reality technologies are thought to capture kids' imaginations and help them pay attention while studying. According to Cunha *et al*. [14], AR can pique children's interest and capture their imagination by allowing them to experiment in safe, alluring situations [15]. This research aims to combine the picture exchange communication systems (PECS) learning technique concept with AR (AutistAR) as a medium of early intervention to improve the social and communicative abilities of children with autism.

Numerous past studies mentioned the utilization of AR in supporting children with autism, such as [16], where the researcher utilized an AR-based video modeling storybook to attract children’s attention management. Magrini *et al*. [17] on the other hand, implemented AR applications to enhance literacy among children with autism. Furthermore, Escobedo *et al*. [18] has also used AR applications to enhance children’s attention management. Based on these findings, there are AR applications available that are built for children with autism, however, there is limited research that has merged PECS into the AR application to enhance communication and social skills among children with autism.

Utilizing mobile devices among those diagnosed with ASD can potentially employ applications that facilitate communication in diverse settings and locations [19]. Furthermore, these devices provide active participation and intervention in the educational processes for families, educators, and families. The portability of these devices will enable users to engage in learning activities anytime and anywhere [20].

Thus, the main theme of the current research is the development and evaluation of an augmented reality application (AutistAR), aimed to enhance the communication and social skills of children with autism. The main goals of the development approach include the integration of PECS in the utilization of AR to facilitate communication and social skills among children with autism, as AR provides an interactive and immersive experience, and makes learning fun and more engaging for the children.

2. DESIGN AND COMPONENTS OF AR APPLICATION

AutistAR is a mobile application specifically designed and developed to cater to the needs of children diagnosed with ASD. Within this particular application, young individuals possess the ability to interact with the displayed text by tapping on it. Consequently, a three-dimensional image will materialize and audibly articulate the specific need, requirement, activity, or emotion that the child intends to convey. The objective of AutistAR is to convert the conventional PECS into an AR application to engage children's attention and facilitate their learning process.

The AutistAR application was created with the Unity game engine and the AR foundation framework. The AR foundation is a framework that enables the development of AR applications across many platforms. The AR foundation framework enables users to engage with AR platforms across the unity development environment. The package provides an interface for developers using unity to implement; however, it does not incorporate any AR functionality. To utilize AR foundation on a designated device, developers are required to obtain a distinct package tailored for the specific platforms supported by unity. Hence, the ARCore XR Plugin was employed and specifically tailored for utilization with Android software in the case of AR.

3. TECHNOLOGIES USED IN AR APPLICATION

AutistAR is based on the latest Android operating system 12.0 technology, text-to-speech, and Picture Exchange Communication Systems (PECS). The application leverages augmented reality to create an engaging and interactive learning environment for children with autism. Additionally, the interfaces cater to the user’s unique needs in both usability and uniqueness. Table 1 displays the technologies employed in the

AutistAR application. Figure 1 outlines the application's user interface and workflow designed to assist children in navigating through different menus and utilizing the AutistAR features.

Table 1. Technologies employed in AR

Category	Items
Operating system	Android 12.0
Components	Text to speech: when children tap the words, it reads aloud
Teaching method for ASD	PECS
Special feature	Children click on words, the AR surface scan will appear, and then the 3D object can be placed on the AR object placement.

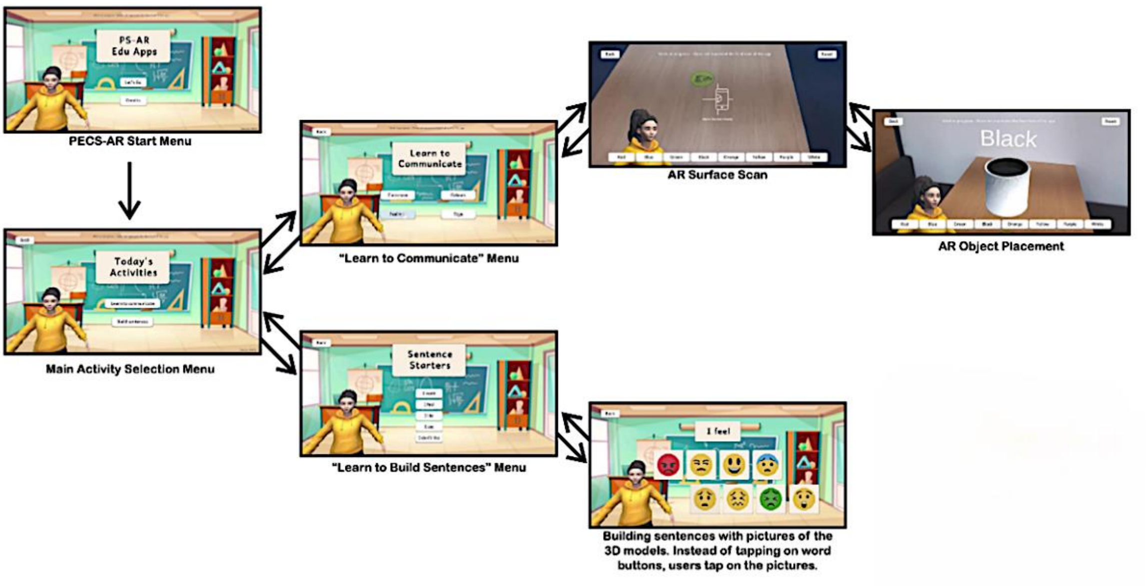

Figure 1. Screenshots of AR application

4. RESEARCH METHOD
4.1. Research design
In the present study, the researcher employed the single-case experimental design (SCED) methodology to investigate the efficacy of the AutistAR application in improving communication and social skills. A SCED is absolute when a control group is difficult or impossible to attain [21]. This experimental design was continued as it enables researchers to examine the methods of the relation between the variables as expressed in an individual's behavior, which led to overt demonstrations of functional relationships among the variables that are being studied.

The SCED is widely used in counseling and special education [22]. It is practical when the researcher tries to influence the behavior of a single individual or a small group of individuals while also documenting the changes. As claimed by Horner *et al*. [23], with this kind of design, the researcher can examine a phenomenon in great detail, contributing to a rich understanding of the research.

4.2. Sample
In order to investigate the efficacy of AutistAR, a sample of two individuals with autism and low verbal abilities was selected from a specialized autism center. The individuals in the study were identified as having ASD, characterized by restricted communication abilities and impaired social skills. Purposive sampling was aided. Both participants attend the center class in 1:1 (student-teacher ratio) for one hour per week at the center. After the parent's consent approval, only two students were selected for this research as the parents allowed them to participate. Hence, Table 2 describes the characteristics of the sample.

Table 2. Sample characteristics (names are not included to maintain anonymity)

Participants		Characteristics
Participant 1	Age	6-year-old
	Diagnosis	Autism index score of 99, level 2 ASD
	Communication and social skills level	Limited verbal and social skills
Participant 2	Age	5-year-old
	Diagnosis	Autism index score of 100, level 2 ASD
	Communication and social skills level	Limited verbal and social skills

4.3. Tools and checklist used

The researcher identified Gilliams Autism Rating Scale, 3rd Ed (GARS-3) to assess the severity of the autism, Children's Communication Checklist, 2nd Ed (CCC-2) as a tool to assess the children's communication skills, and Social Responsive Scale, 2nd Ed (SRS-2) as a tool to measure the children's social skills. These assessment tools were chosen based on their reliability and validity in diagnosing and measuring various aspects of ASD. The use of these standardized tools ensures a comprehensive evaluation, enabling targeted intervention strategies.

4.4. Training settings and sessions

The intervention was administered throughout 12 sessions, with a teacher-to-participant ratio of 1:1, including two individuals. Each session had an approximate duration of one hour per week. A pre-test and a post-test were taken before and after the intervention sessions. The special needs teacher utilized the AutistAR application during the teaching and learning period.

4.5. Material used and procedure

The study utilized AutistAR, a freely available application designed for children with autism. The intervention used a Samsung S7 tablet, with an Android 13, and 5.0 MP camera features. The instruction was given at the autism center to implement the application during the intervention session. The researcher demonstrated the application to the special needs teacher of the participants focusing on the AR surface scan and AR object placement. The intervention was conducted for 12 weeks.

4.6. Data collection

Visual analysis of graphic displays was used in this SCED. The data are graphed for each participant during the research with the trend, level, and stability of the data assessed within and between a condition. The participant's performance is calculated and transferred to a graph to visually analyze the trend, level, and stability. The researcher selects the format of displaying the data that best reflects the study according to the research questions. Thus, in current research, bar graphs and line graphs were used.

4.7. Ethical procedures

To carry out this research, consent was obtained from the participants' parents, who were briefed on the confidentiality and privacy measures in place for safeguarding the data throughout the research. Additionally, prior approvals were secured from the Ministry of Education Malaysia (MoE) and permission was granted by the Kuching Autistic Association. Ethical considerations were meticulously addressed to ensure the rights and well-being of the participants were protected. Moreover, regular updates and open communication channels were maintained with the parents and guardians to keep them informed of the progress and any significant findings of the study.

5. RESULTS AND DISCUSSION

Table 3, Table 4, and Figure 2 depict the progress in communication skills among the two participants, who had limited verbal and social skills before and after using the AR application. While Table 5, Table 6, and Figure 3 show the progress among the two participants in social skills. The special needs teachers seldom implemented PECS during their teaching and learning sessions. The AutistAR application was designed to mitigate the tedious task of creating flashcards and image cards. Additionally, it considers that children in the contemporary day exhibit a greater inclination towards technology.

Participant 1 demonstrated a difference in his communication abilities before and after the intervention, scoring 3 and 7 on the SIDI before and after, respectively, and having a GCC sum of 30 (before) and 55 (after). All subscales under the CCC-2 checklist revealed improvements before and after the intervention. Moreover, for social skills, participant 1 exhibited a difference in his social skills before and after the intervention, with a T-score of 62 (total raw score=72) after the intervention and a T-score of 70 (total raw score=93) previously. The total T-score of SCI is 64 (raw score=67) based on the DSM-5 compatible subscales before and 60 (raw score=58) after the intervention. Additionally, the T-score for the RRB subscale is 72 before the intervention (raw score=16) and 68 after the intervention (raw score=14). The SRS-2 subscales all showed improvement after the intervention.

Furthermore, with a GCC sum of 57 (before) and 53 (after) and scores of 3 and 5 on the SIDI before and after the intervention, respectively, participant 2 demonstrated a difference in her communication skills. Only two subscales, the speech subscale and the inadequate initiation subscale do not change after the implementation of AutistAR. For the social skills on the other hand, participant 2 showed a difference in her social abilities before and after the intervention, with a T-score of 67 (total raw score=86) before and a T-score of 56 (total raw score=58) after. The total T-score of SCI is 64 (raw score=68) based on the DSM-5 compatible subscales before and 57 (raw score=51) after the intervention. Additionally, for the RRB subscale, the T-score before the intervention is 76 (raw score=18), whereas the T-score after the intervention is 54 (raw score=11).

The results of this study provided evidence to support the assertion that AR technology can deliver a significant and pleasurable user experience [24]. Several studies [16], [25] have documented the positive impact of AR applications on the development of social communication skills and their potential to enhance learning by providing a stimulating and cognitively demanding experience. This is in line with a study conducted by Taryadi and Kurniawan [26], the qualitative exploration of communication skills using AR-PECS stipulated the average performance of children was 47% before the intervention. Their performance improved to 65% during the intervention session and increased to 76% after the intervention.

Table 3. Participant 1 communication skills before and after the intervention according to each subscale

Subscales	Before			After		
	Raw score	Scaled score	Percentile rank	Raw score	Scaled score	Percentile rank
A) Speech	9	7	16.0	8	8	26.0
B) Syntax	12	4	2.0	8	7	16.0
C) Semantics	13	4	2.0	8	8	25.0
D) Coherence	15	3	1.0	8	7	16.0
E) Inadequate initiation	11	7	16.0	7	10	50.0
F) Scripted language	8	6	9.0	7	7	16.0
G) Context	12	5	5.0	10	7	16.0
H) Non-verbal communication	11	4	2.0	8	6	9.0
I) Social relations	8	6	9.0	5	8	25.0
J) Interests	14	4	2.0	10	7	16.0

Table 4. Participant 2 communication skills before and after the intervention according to each subscale

Subscales	Before			After		
	Raw score	Scaled score	Percentile rank	Raw score	Scaled score	Percentile rank
A) Speech	11	6	9.0	11	6	9.0
B) Syntax	13	4	2.0	8	7	16.0
C) Semantics	11	5	5.0	6	9	37.0
D) Coherence	10	6	9.0	7	8	25.0
E) Inadequate initiation	8	9	37.0	8	9	37.0
F) Scripted language	9	5	5.0	4	9	37.0
G) Context	11	4	2.0	7	9	37.0
H) Non-verbal communication	8	6	9.0	6	8	25.0
I) Social relations	8	6	9.0	6	7	16.0
J) Interests	11	6	9.0	9	8	25.0

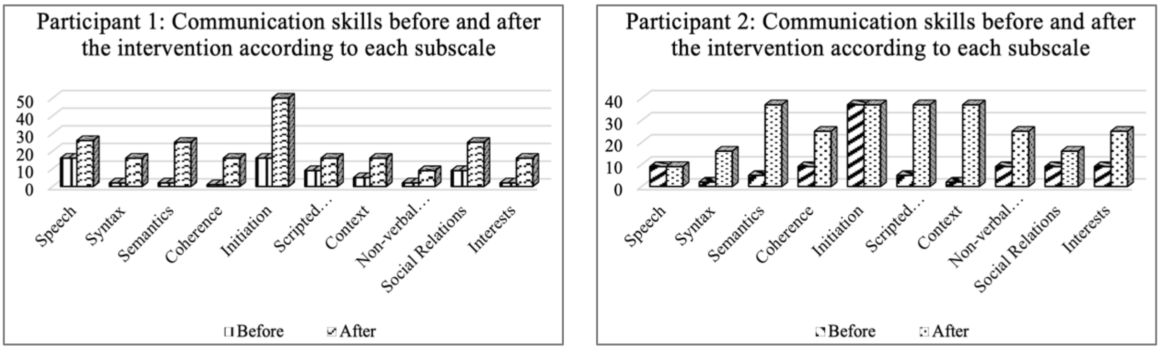

Figure 2. Communication skills before and after the intervention

Table 5. Participant 1 social skills before and after the intervention according to each subscale

Subscales	Before		After	
	Raw score	T-score	Raw score	T-score
A) Awareness	15	71	14	68
B) Cognition	21	71	9	51
C) Communication	29	66	27	65
D) Motivation	12	59	8	53
E) Repetitive behavior	16	71	14	68

Table 6. Participant 2 social skills before and after the intervention according to each subscale

Subscales	Before		After	
	Raw score	T-score	Raw score	T-score
A) Awareness	15	71	8	51
B) Cognition	15	61	12	56
C) Communication	25	62	20	58
D) Motivation	13	62	11	58
E) Repetitive behavior	18	77	7	54

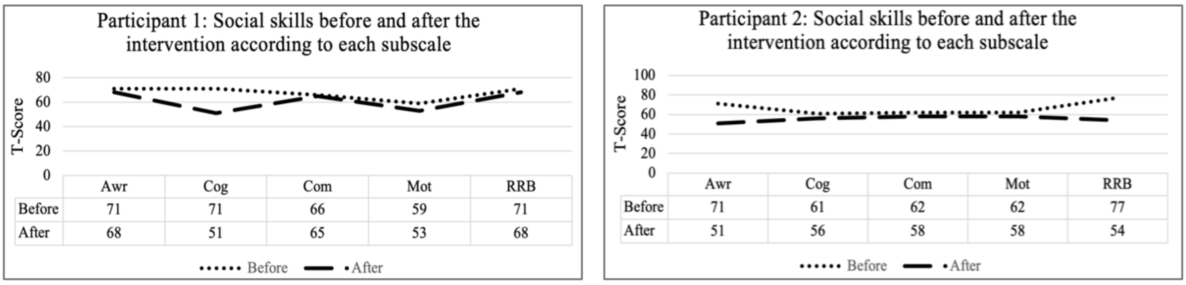

Figure 3. Social skills before and after the intervention

Based on the results, AutistAR seems to enhance communication and social skills among children with autism positively. The development of AR applications can be beneficial in treating this developmental disorder. This is because AR is built on the traits frequently associated with ASD such as visual learning style or preference for visually displayed information [27]. AR technology enables the creation of engagement in learning which supports children with autism to maintain their attention, encouraging engagement, and motivation that enhance the learning process [18], [28]. Apart from that, PECS is one of the effective techniques that has been widely used for children with autism and is believed can help in communication skills [29]. Innumerable past research has supported the use of PECS focusing on communication [30]. Thus, integrating PECS in AR application in current research (AutistAR) showed an improvement in the participants' communication and social skills. However, the application still needs to be upgraded to achieve better results and can be used for other children with autism at different ages.

AutistAR application stands out from other applications because of its unique functionality. Its features allow children to perceive the image in 3D and let the children place the 3D objects in the AR object placement according to their interests. The application also includes all six phases of PECS, from Phase I (how to communicate) until Phase XI (commenting in response to a question).

6. CONCLUSION

The AR application is exclusively compatible with smartphones operating on the Android operating system. Mobile applications can use scientific teaching methods for children with Autism and other special needs for different operating systems, such as Apple phones, which mobile users frequently use. Due to the time constraints and the parents' consent, the research only included 2 participants for a brief period; however, in the near future, it may be applied to a larger sample for a longer duration. The application requires training and awareness, especially among special needs teachers and parents. Although the application is free, only the smartphone with the latest Android operating system is able to download from the Play Store, which not every parent can afford. Future educational mobile applications could be developed to teach children with autism and other special needs in various aspects, namely personal skills, sensory skills, behavioral aspects, and recreational skills in other special education aspects. This is the first step towards educating children with autism, and hopefully, this technology will be used more effectively in the future.

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