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Reducing stereotypical behaviors using augmented reality in children with autism spectrum disorder

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Abstract

Augmented reality (AR) has been shown to have a positive impact on children with autism spectrum disorder (ASD) because it can effectively simulate the real environment through interactive experiences created by the integration of digital elements with the outside world. This research aimed to verify the effectiveness of a training program based on AR for reducing stereotypical behavior (SB) in a sample of children with ASD. The study sample consisted of 16 male students with ASD who were enrolled in the Autism Institute in Al-Ahsa, Saudi Arabia, ranging from 8 to 13 years of age. The researcher also developed a training program and employed a quasi-experimental method in addition to research instruments including the Stereotypic Behavior Scale (SBS). The results of the analysis show statistically significant differences between the mean ranks of the participants in the three tests (pre-, post- and follow-up) on the SBS ($x2 = 30.471$, $p < 0.001$) which indicates the effectiveness of AR in reducing participants' SB. Additionally, it demonstrates that the training impact lasts for two months after the end of the program. According to the research, AR-based software applications have the potential to improve children with ASD's socialization and interaction abilities. It is recommended to do additional research using larger sample sizes and controlled designs.

Keywords: Augmented reality, Autism spectrum disorder, Behavior modification, Educational technologies, Saudi Arabia, Stereotypical behaviors.

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Contents

Contribution of this paper to the literature
The results of this study are useful for specialists, teachers and educational researchers regarding how augmented reality affects reducing stereotypical behavior in children with moderate autism spectrum disorder in Saudi Arabia. Policymakers, practitioners and educational administrators can also use the research findings to plan the effective use of augmented reality to reduce socially unacceptable behaviors in these children.

1. Introduction

The past decade has seen a rise in studies and research on technology-based interventions for autism spectrum disorder (ASD). Assessments and intervention tools based on augmented reality (AR) are particularly promising as research suggests a direct correlation between the use of technology and AR and the development of numerous behaviors and social skills in ASD children. The use of augmented reality (AR) in education has been shown to be acceptable to students with ASD and to be beneficial in helping them develop their social skills. It also gives these children a secure and regulated learning environment to solve social problems. However, there is a need for research and studies that apply AR using more rigorous designs and well-established, evidence-based intervention strategies (Dechsling et al., 2022; Hassan, 2022; Lledó, Lledó, Gilabert-Cerdá, & Lorenzo-Lledó, 2022).

Lack of communication and the ability to respond correctly in social circumstances through body language and facial expressions are common in children identified as having Autism Spectrum Disorder (ASD). This negatively affects the quality of their daily lives. However, children with ASD can learn to interact socially with 3D) virtual characters in animated games that are enhanced with AR where they can recognize body language and facial expressions (Lee, 2021).

There are many training programs for dealing with these socially unacceptable behaviors in these children but more research is still needed to determine how effective it is to use AR as a training tool. SBs in children with ASD represent a significant challenge for them in social and educational contexts. The research proposes a new educational method using AR to reduce social behavioral disorder (SBD) in children with ASD aiming to positively impact their behavior.

The research highlights the importance of AR training programs for children with ASD due to their effectiveness in reducing socially unacceptable behaviors, including stereotypical ones. This research fills a gap in both the Arab and international literature on AR-based training programs for ASD. It also aimed to prepare a program and scale for measuring SBs in children with ASD introducing future research on AR-based training for neurodevelopmental disabilities in general and children with ASD in particular.

The present investigation aimed to address the following main research question in view of the aforementioned discourse:

RQ1. Are there statistically significant differences between the mean ranks of the participants in three tests (pre, post-, and follow-up) on the Stereotypic Behavior Scale (SBS)?

The study hypotheses are as follows:

H0. There are no statistically significant differences between the mean ranks of the participants in the three tests (pre-, post-, and follow-up) on the Stereotypic Behavior Scale (SBS).

H1. There are statistically significant differences between the mean ranks of the participants in the three tests (pre-, post-, and follow-up) on the Stereotypic Behavior Scale (SBS).

2. Literature Review

2.1. Autism Spectrum Disorder

Children and adults with ASD are unable to appropriately comprehend what they see, hear and feel. It is a developmental condition that affects both people in their lifetime. This means they can face serious problems in their social and communicative relationships and stereotypical behaviors (Chaidi & Drigas, 2023). These problems can be accompanied by psychological problems, anxiety and depression (Vormer, 2020). ASD can be identified by a specific set of behaviors and is often referred to as a "spectrum condition" that affects children differently and to varying degrees. A child with an early diagnosis can receive the assistance and services they require, thereby facilitating their successful integration into society even if there is currently no cause of ASD (Autism Society, 2024).

Autism spectrum disorders have an impact on social expression which is important for reciprocity and good communication because it teaches children to identify nonverbal clues, feel other people's feelings, pay attention together and use nonverbal social skills (Lee, Chen, Wang, & Chung, 2018).

According to the fifth edition of the Diagnostic and Statistical Manual of Mental Disorders (DSM-5) issued in 2013, ASD is characterized by the following: (1) deficiencies in social communication and interaction and (2) limited and repetitive behavior, interests and activities (American Psychiatric Association, 2013). According to Omar (2018) the same guide indicates that children with ASD show SBs by participating in a restricted set of stereotyped activities. These are: (1) excessive and continuous preoccupation with one or more SBs that are abnormal in terms of their nature or intensity (2) Abnormal attachment to some stereotypical habits or behaviors that have no meaning or significance. (3) Making stereotypical and repetitive physical movements such as flapping the hands or fingers or bending the torso forward and backward. (4) Intense fascination with some parts of objects and playing with them.

Therefore, limited and repetitive patterns of behavior, interests or activities are displayed by children with ASD. These patterns can be seen in their speech, motor skills and routines and include things like flapping their hands, walking on tiptoes, moving their body back and forth, becoming excessively preoccupied with parts of objects and playing with them for extended periods of time and repeating words without realizing what they are doing (Morgan, 2019; Noriega, 2021). These patterns can be stereotypical or repetitive and children with ASD can suffer from extreme distress or difficulties in transition when they attempt to make small changes. Additionally, they may have fixed and restricted interests that are highly abnormal in intensity or focus, over- or under-reactivity to

sensory input or an unusual interest in sensory aspects of the environment. These patterns can be observed in various aspects of their lives (American Psychiatric Association, 2013).

These issues have been confirmed by several studies including Sadaf et al. (2020) which investigated the relationship between sensory difficulties and SB in children with ASD. He showed a clear correlation between both problems: the recurrence of stereotyped behavior increased with the level of sensory deviations. In children with ASD, the most prevalent behaviors that emerged as a result of sensory difficulties were self-injurious and obsessive behaviors.

Many experimental studies have indicated that children with ASD suffer from stereotypical and repetitive movements. Additionally, these studies have decreased the children's SBs through their training programs that are based on several different methods. According to research by Ferreira et al. (2019), physical activity significantly reduced the incidence of SBs in children with ASD. Furthermore, Jubali and Sakri (2021) investigated the utility of sensory integration for reducing SB (licking certain objects that are not eaten) in children with ASD in Tunisia while Jafar (2022) demonstrated the effectiveness of a program based on evidence-based practice (EBP) for reducing anger and the severity of rejection SBs in children with ASD in Saudi Arabia. In Egypt, Atwa (2021) demonstrated the effectiveness of motor activities in reducing repetitive SB and improving social interaction in children with ASD. Fayed, Abdel Halim, and Al-Sayed (2022) demonstrated the effectiveness of applied behavior analysis techniques in reducing repetitive SB (sensory SB, verbal SB, motor SB, emotional SB and routine SB) in such children. Al-Farkh (2023) verified the effectiveness of group games and the continued effect of their effectiveness in reducing SB (repetitive behavior, rigid behavior, motives, obsessions, repetition and stereotyping in the use of language or various body movements) in children with ASD. Hafez, Ghazal, and Hassan (2023) demonstrated the effectiveness of a training program based on sensory integration strategies in reducing SB (motor, vocal and visual) for such children. In addition, Saeid (2023) showed the effectiveness of a training program based on brain sports for reducing SB (sensory SB, verbal SB, motor SB, emotional SB and routine SB) in children with ASD.

2.2. Augmented Reality

Various developing technologies of recent years such as augmented reality (AR) have greatly benefited students and have played an important role in the development of everyday activities in today's society (Lledó et al., 2022). AR is seen as an emergent, widely available, low-cost fundamental technology in addition to the spread of smartphones and tablets. There is a lot of promise for this technology in education and several augmented reality applications have been created to teach STEM disciplines (science, technology, engineering and math) (Mukhtarkyzy, Abildinova, Serik, Kariyeva, & Sayakov, 2023). AR is also considered one of the most popular technologies for its versatility in general and special education as it is characterized by many application possibilities (Lorenzo, Lorenzo, Lledó, & Pérez-Vázquez, 2023b). AR is considered a computer technology that can connect the virtual world with real reality through technical applications, tablets and smartphones. It can support cognitive content through three-dimensional images, videos and other forms and means of illustration in a way that attracts attention which encourages children to interact more with scientific material and link it to their real-life situations (Goda, 2018). AR technology offers additional possibilities for independent practice, more ways for children to actively participate in learning and additional ways for them to depict concepts. It can also assist special education teachers in implementing numerous evidence-based methods (Howorth, Rooks-Ellis, Flanagan, & Ok, 2019).

Both AR and virtual reality (VR) provide new experiences in the simulation and digital worlds and although AR differs from VR, both types of reality aim to stimulate children's perceptions and senses in general (Samala et al., 2023).

Peddie (2017) argues that AR has taken longer to develop than VR due to its greater technological requirements. However, the basic components needed for AR systems have remained consistent since Ivan Sutherland's 1960s work. AR devices use technologies like GPUs, display devices and optics to operate, create images, and direct them into the field of view as shown in Figure 1.

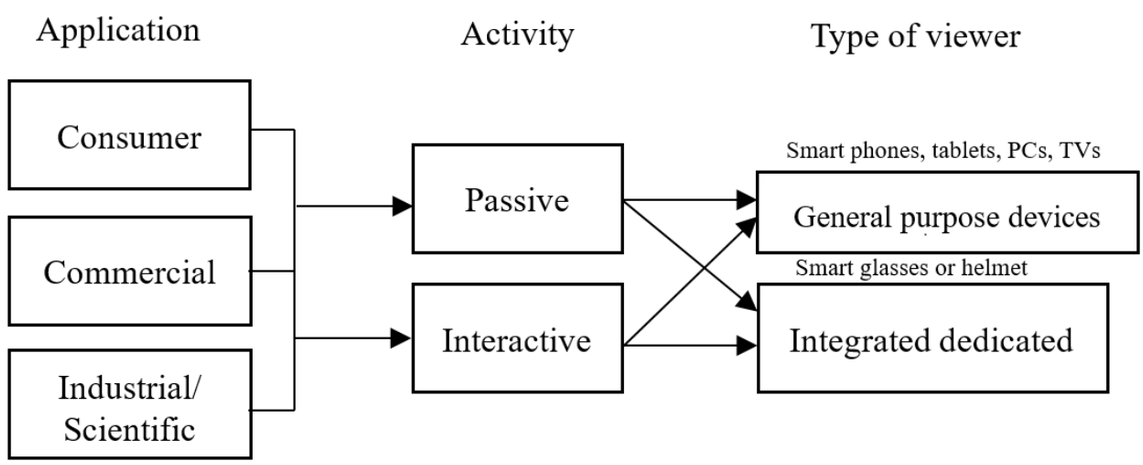

Figure 1. AR is used for different devices and in different applications.

A systematic literature review by Mosher and Carreon (2021) examined the use of AR, VR and mixed reality (MR) in teaching social skills to children with ASD. The review found that AR/VR interventions were effective in 63% of studies while VR interventions were ineffective in 10%. Hence, the authors suggest that combining these technologies could be more effective.

Lorenzo, Gilabert, Lledó, and Lorenzo-Lledó (2023a) report a growing interest in AR applications for children with ASD. They analyzed global trends and used bibliometric techniques to identify the potential integration of technological tools for improving AR scenarios and areas that work best with children with ASD.

Many researchers have addressed the effective role played by AR in developing various skills in children with ASD. For example, Cihak et al. (2016) sought to investigate the impact of AR on teaching three primary school students suffering from ASD where a typical video of a student brushing her teeth was used. The authors demonstrated that the three children learned how to brush their teeth independently and maintained this skill. This evidence-based study demonstrated that after completing the nine-week AR intervention, the children were able to concentrate on social cues because AR captivated their attention. Lee et al. (2018) also showed that AR is effective in teaching social skills. However, there is a lack of AR applications to help these children organize their educational materials. Howorth et al. (2019) attempted to develop ideas on how AR applications can be used with students with ASD to develop reading skills by (a) teaching phonics and word identification, (b) supporting reading fluency, (c) embedding videos into texts as cues for reading comprehension, (d) teaching vocabulary words, and (e) using video models while transition planning.

The effectiveness of a VR-based joint attention task platform to reveal deficiencies in joint attention abilities was proven by Jyoti and Lahiri's (2019) study on 20 individuals with ASD and typically developing participants. The participants showed superior finger signal picking than eye signal following. Lee (2021) suggests that current virtual role-playing models are limited by their focus on body language and facial expressions and lack real interaction with children with ASD. Hence, a system allowing trainers to control 3D (three-dimensional) virtual characters is needed. Root, Cox, Davis, and Gonzales (2022) evaluated a multicomponent intervention involving a modified schema-based instruction and an AR video-based instruction for teaching social and mathematical problem-solving skills to 21-year-olds with ASD, demonstrating its effectiveness and ability to self-correct errors. Hamid, Al-Namroti, Al-Sulaiti, and Alhader (2022) also investigated the efficacy of AR for developing non-verbal communication skills among children with ASD in Qatar. The results of this study showed the effectiveness of applying AR to develop basic human emotion recognition skills (happiness, surprise, sadness, anger, fear and pain) in children. The results also demonstrated the development of some adaptive behaviors in social situations such as awareness of selected sources of danger such as drowning and electricity.

3. Materials and Methods

3.1. Research Design and Setting

The research adopted a quasi-experimental approach to reflect the nature of the research to verify the effectiveness of a training program based on AR (the independent variable) for reducing SB (the dependent variable) in children with ASD (the target sample). A one-group design was used and three tests were applied (pre-, post-, and follow-up) to verify the effectiveness of the program used and the continuity of the training effect after the end of the program's application period of two months.

3.2. Participants

The research population included all children with moderate-level ASD who were enrolled in the Autism Institute in Al-Ahsa, Saudi Arabia. According to official statistics issued by the institute, the estimated number in the first semester of the 2023–2024 academic year was 111 children ranging from 8 to 13 years of age. An exploratory sample included 40 children from the institute while the basic sample included 16 children who were intentionally chosen because they were diagnosed with moderate ASD and were all males. The focus of this study was on males due to the nature of the scientific research application in the Kingdom of Saudi Arabia where only male teachers and researchers can work with male children and only female teachers and researchers can train female children. Table 1 provides demographic information about the study participants.

Table 1. Demographic characteristics of participants (N=16).

Characteristics	n	%
Gender (male)	16	100
Institute (Autism institute)	16	100
	Mean	SD
Age	10.56	1.63
IQ score	47.19	2.86
Severity of ASD	34.88	1.02
Severity of SB	35.06	0.85

3.3. Research Tools

3.3.1. Stereotypic Behavior Scale (SBS)

The researcher prepared the SBS scale to measure SB in children with moderate ASD for this research. This was supported by the fact that no scale exists in Saudi Arabia for measuring SB in children with moderate ASD. The scale was developed in light of the diagnostic criteria contained in the DSM-5 issued in 2022. The scale in its final form consisted of 24 statements each with a three-point Likert responses scale (1 = does not apply, 2 = sometimes applies and 3 = always applies). The possible score ranged from 24 to 72 with a score lower than the mean indicating a low level of SB and a score higher than the mean indicating a high level of SB.

The psychometric efficiency of the SBS was verified on an exploratory sample consisting of 40 boys and girls from the Autism Institute in Al-Ahsa by calculating the validity of the correlative test with the Gilliam Autism Rating Scale (GARS-3) developed by Gilliam (2014) as an external tester. The correlation coefficient reached 0.764. The internal consistency of the scale was also calculated and the correlation coefficients ranged from 0.503–0.802. The reliability of the scale was also calculated using Cronbach alpha and achieved a coefficient of 0.850. The reliability of the scale was also calculated using the retest method. The correlation coefficient reached 0.791 three weeks after the scale was initially used, indicating that the scale had psychometric efficiency and could be used with confidence.

3.3.2. Training Program

An AR training program that aimed to reduce SB was prepared for children with ASD. The program was presented to seven reviewers to determine its validity and the researcher made the necessary modifications before applying the program to the participants. The program's aims were outlined including its overall goal of reducing SB in children with mild ASD. Its significance, the theoretical underpinnings of the program and the methods employed were also addressed. The program was crucial because children with ASD experience social anxiety (SB), a condition that hinders social engagement and conversation with others and keeps these kids out of social situations. This causes many psychological pressures for these children and parental pressures for their families. Hence, the training program was important for modifying the behavior of these children to ensure their integration into society in an acceptable manner.

In its content and techniques, the program was based on the foundations of behavioral theory. This influenced program elements such as the training program's content being appropriate for the needs and characteristics of children with ASD, the program's gradual progression from easy to difficult and the incorporation of images and videos into its activities. It also affected the researcher's relationship with the research sample. In the context of nature, these exercises relied on individual and group work, a variety of reinforcement techniques, training that lasted long enough to guarantee participants' reduction in SB and an objective for performance of up to 80% as compared to 100%. The five phases of Addie's model analysis, design, development, implementation and evaluation were also the basis of the training curriculum (Jusoh, Rashid, & Handrianto, 2022; Sahaat, Nasri, & Bakar, 2020).

The procedural limits of the program were to select the participants with ASD from those registered at the Autism Institute in Al-Ahsa. The program was implemented across a total of 40 sessions, three sessions per week, with the duration of each session being 10 minutes individually for each child, up to 160 minutes per session, across more than three months from August to November 2023. The program included a variety of strategies such as role-playing, modelling, indoctrination, individualizing instruction, analyzing assignments and providing feedback and reinforcement. The three phases of the training program were as follows: The three sessions that comprised the first stage or introductory stage, covered a number of fundamental topics. These consisted of getting to know the children and each other better to foster greater familiarity and harmony engaging in child-friendly events and giving them reinforcement. The second stage (training stage) included 30 sessions in which training was given to reduce routine SB (sessions 4–9), reduce emotional SB (sessions 10–15), reduce motor SB (sessions 16–21), reduce verbal SB (sessions 22–27) and reduce sensory SB (sessions 28–33). The successful involvement of AR in lowering socially undesirable behaviors was undertaken by participants through the website "UniteAr" and the employment of programs such as Photoshop, Illustrator and Blender. The third stage (the evaluation stage) included seven sessions (sessions 34–40), where the participants were evaluated according to forms specifically designed to evaluate performance on required activities. It was required that the participants obtain a percentage of not less than 80% from the set of attempts.

3.4. Data Collection

This research relied on reviewing official records at the Autism Institute in Al-Ahsa to collect relevant data on age, intelligence and the degree of ASD. Tools that have a high degree of validity and reliability in detecting intelligence and the degree of ASD such as the Stanford-Binet Intelligence Scale (fifth edition) and GARS-3 were used. Children who were evaluated on these tools for more than six months were excluded from the research.

3.5. Statistical Analysis

Statistical analysis was performed using Jeffreys's Amazing Statistics Program (JASP) version 18. The Friedman test which is a non-parametric test that calculates ranks instead of values was used for the analyses. It is an alternative to the parametric test and analysis of variance for repeated measures. The Wilcoxon test was also used in post-hoc comparisons to identify the source of the difference between paired samples.

4. Results

H0. There are no statistically significant differences between the mean ranks of the participants in the three tests (pre-, post-, and follow-up) on the Stereotypic Behavior Scale (SBS).

The collected data were analyzed using the Friedman test and the Kruskal-Wallis test for significant differences. The results of the data analysis are shown below.

Table 2 shows the results of $x^2 = 30.471$ and $p < 0.001$ which is smaller than $p = 0.01$. Therefore, we reject the null hypothesis which states that there are no statistically significant differences between the mean ranks of the sample scores on the three tests (pre-, post- and follow-up) on the SBS and we accept the alternative hypothesis which states that there are statistically significant differences between the mean ranks of the sample scores in the three tests (pre-, post- and follow-up) on the SBS in favor of the best mean rank; this was for the post-test and reached 1.41. We used the following formula to determine the training program's effect size:

$$W = \frac{X^2}{\mathrm{N(K-1)}}$$

Where W represents the value of the effect size (Kendall value) (medium effect) or higher than 0.5 (large effect) (Tomczak & Tomczak, 2014). The calculated effect size for the training program was 0.95 which is considered a large effect size.

Table 2. Results of the Friedman test for the significance of differences between the three tests.

Tests	Mean	Mean rank	X^2	P	W
Pre-test	53.06	3	30.471	< 0.001	0.95
Post-test	34.94	1.41			
Follow-up test	35.19	1.59			

Table 3 shows that the post-test was the better test with a mean score of 34.94 compared to 53.06 for the pre-test participants. The z-value for the pre- and post-tests was -3.561, $p < 0.001$ which was less than $p = 0.01$. These differences in mean rankings on the SBS are statistically significant in favor of the post-test.

The presence of statistically significant differences between the mean ranks for the pre-test (mean = 53.06) and follow-up test (mean = 35.19) participants on the SBS was in favor of the better test which was the follow-up test as the z-value for the pre- and post-tests was -3.540, $p < 0.001$ which was less than p-value = 0.01. In addition, there were no statistically significant differences between the mean ranks for the post-test (mean = 34.94) and follow-up test (mean = 35.19) participants on the SBS where the Z for the pre- and post-tests was -1.633, $p = 0.102$ which was higher than $p = 0.01$. This indicates the effectiveness of the training program and the continued impact of the training after the end of the program application period.

Table 3. Results of the Wilcoxon test for the difference between the mean ranks of the paired groups.

Tests (Mean)	Rank	N	Mean rank	Total ranks	Z	*P*
Pre-test (53.06)	-	16	8.5	136	-3.561	< 0.001
Post-test (34.94)	+	0	0	0		
Pre- test (53.06)	-	16	8.5	136	-3.540	< 0.001
Follow-up test (35.19)	+	0	0	0		
Post-test (34.94)	-	0	0	0	-1.633	0.102
Follow-up test (35.19)	+	3	2	6		

5. Discussion

The results of the study confirm the effectiveness of using AR to reduce SB in the participants (children with moderate ASD) and the continued positive impact of the program two months after the end of the intervention. These results are consistent with several studies that have targeted skill development such as the study by Cihak et al. (2016) which indicated that AR was effective in developing some self-care skills among children with ASD and maintaining the effect of the training two months after the program was implemented. The results of this study are also consistent with other research. For example, Jyoti and Lahiri (2019) demonstrated the effective role that AR plays in improving joint attention skills in children with ASD while Mosher and Carreon (2021) indicated the effectiveness of AR in teaching social skills to children with ASD, motivating them towards the intervention and fostering positive attitude towards technology, especially if AR is mixed with VR. Their results also indicated that intervention is also effective for improving the social skills of these children. Furthermore, Lledó et al. (2022) demonstrated the role of AR in improving the development of daily life activities in children with three degrees of ASD, Hassan (2022) showed positive effects of AR on developing expressive language and improving the level of spontaneous speech among a sample of children with ASD and Root et al. (2022) results revealed the effectiveness of using AR and modified diagram-based instructions to teach problem-solving to children with ASD and correct their self-errors after watching typical video clips. Finally, Hamid et al. (2022) revealed the impact of AR technology on developing some non-verbal communication skills in children with ASD.

These results also indirectly indicate that training programs based on EBP in general (e.g., sensory integration, motor activities, applied behavior analysis, group games and sensory integration strategies) can reduce SB and increase the level of social interaction in children with ASD consistent with studies by Atwa (2021); Jubali and Sakri (2021); Jafar (2022); Fayed et al. (2022); Al-Farkh (2023); Hafez et al. (2023) and Saeid (2023). The findings of this study can be explained by the discussion made by Lledó et al. (2022) regarding the primary and crucial role that emerging technologies play in society for the development of daily life activities. AR is at the forefront of these technologies and has proven to be extremely beneficial for children with a variety of disabilities. Recently, Lorenzo et al. (2023b) provided an explanation of the many applications of augmented reality (AR) in education particularly in the area of special education where the technology's potential for use is apparent.

The findings of this study support the claims made by Howorth et al. (2019) that augmented reality (AR) technology can assist special education teachers in implementing evidence-based practices (EBPs), increase opportunities for independent practice and improve participation and concept representation for children with ASD. The researcher also attributes the reduction of SB among the participants in this research to the efficiency of AR because it is not only a technology that can be used to develop communication skills, social interaction skills and other skills but it also has an amazing ability to modify socially unacceptable behaviors including SB in children with ASD as long as their use is directed to the needs and abilities of these children ensuring an environment that is conducive and supportive to achieving desired goals. Children can observe and interact with virtual aspects in their real environment due to the program employed in this study which comprised several interactive activities that combined the real world with well-known virtual features. The implementation of these activities involved offering students meaningful and instructive experiences that assisted in the development of their social and communication skills thereby reducing SB and positively enhancing skill development. The children's routine and their suffering from an attachment to technology and its advantages were exploited by the researcher. Children with Autism Spectrum Disorder (ASD) are attracted to visually appealing and captivating effects. As a result, augmented reality (AR) was used to create social simulations that allowed students to safely and comfortably interact with others, understand others and express their emotions.

The researcher was keen to use AR and after taking the opinions of experts in the field of educational technology and specialists in the field of ASD into account, these exercises were carefully used and led to improving the independence of the participants and enhancing their ability to live independently after reducing their SB. These training activities included a variety of techniques such as organizing, problem-solving and planning to assist the participants become more skilled at mental and cognitive processes, less focused on specific tasks or details and more focused and attentive. Reducing deviant or repetitive motions and increasing motor coordination and flexibility also helped students with ASD develop better motor abilities. The individual's proficiency in spoken and non-spoken language, communication, expressing desires and needs and some social skills were enhanced. This was evidenced through their cooperating with others, expressing feelings,

understanding the feelings and emotions of others, making eye contact, responding to social initiatives and participating in social activities. According to the researcher, some of the reasons for these results could be attributed to the tablets' easy and appealing use of augmented reality (AR), the availability of vibrant, appealing colors for children to play with and virtual elements that resembled the participants' homes and the use of child-focused strategies like participatory, direct and pictorial modelling which all worked to hold children's interest for as long as possible.

6. Conclusion

The results of the current research showed that the use of AR can have a positive effect on reducing SB in participants as the interactive experience of the research provided opportunities for training and effective participation, properly invested leisure time in the participants and improved their behavior. This means that AR can be viewed as one type of intervention within a group of evidence-based behavioral interventions used with children with ASD rather than implying that it can be used as the only intervention for decreasing unacceptable behaviors represented by SB in these children.

Therefore, this technology should be used as part of a comprehensive program aimed at modifying socially unacceptable behaviors and enhancing communication and social interaction in children with ASD. It is recommended that further research be conducted to determine the factors that affect the effectiveness of this technology and the optimal time frame for benefiting from it. Future research should include larger samples of children with ASD with varying severity (mild, moderate and severe) and use advanced research methodologies to achieve more accurate and generalizable results. AR can be applied correctly and effectively by holding workshops, awareness sessions and collaborative discussions to share knowledge and experiences and develop strategies. The significance of guidance research intended for the families of children with ASD and experimental research aimed at the teachers of these children which allows for cooperation between families, teachers and specialists in the field of autism should be recognised. Children with ASD can benefit from customized AR programs. Positive interactions and communication with them together with the use of positive incentives and motivating learning strategies are all important ways to reinforce positive behaviors. These programs could make use of mixed reality (MR) virtual reality and augmented reality to offer interactive experiences that improve social interaction and acceptable behavior standards.

7. Limitations and Future Research

The study's sample size (n = 16) was one of the limitations. It was chosen to focus on children with mild ASD which decreased the possibility of generalization. As a result, the findings are limited to these students in Al-Ahsa in order to get more precise and broadly applicable findings. The sample size should be raised in further studies. The research was also restricted to children with moderate ASD only in order to avoid discrepancies that may occur due to the different effects of AR on SB among the children participating in the research because little is known about how this disorder varies in severity from simple to severe. AR may also have a temporary effect on SB in children with moderate ASD. Therefore, these children should be monitored over an extended period of time in order to assess the technique's ongoing efficacy and its impact on lowering SB.

As a result, the researcher did not use homework to provide feedback to the research sample and did not expose the participants to any other interventions during the program's application. These external factors which could have also affected the effectiveness of AR in reducing SB were taken into consideration for analysis and interpretation to ensure unbiased results. Therefore, it is suggested that future studies address these limitations and use advanced research methodologies to achieve more accurate and generalizable results on reducing SB using AR in children with ASD. Research with a sample of children with ASD classified into groups according to severity levels ranging from moderate to severe is one idea for future investigations. The findings of this study may be used to ascertain if the efficacy of augmented reality varies among these classifications. Research can also be done to assess the effect of AR on lowering SB in children with ASD in various applications like homes and intervention centers. The findings of this study can be used to assess the efficacy of AR technology in different situations and offer suggestions for how best to apply it regardless of the use of diverse groups.

Research can also be conducted to evaluate the effectiveness of this technique for different age groups such as children less than six years of age, adolescents, and young adults. The results of this research can help determine whether the effectiveness of this technique differs between these different age groups or not. A long-term study can also be conducted to evaluate the continued effectiveness of AR in reducing SB in children with ASD. Such children can be followed over several years to determine whether the positive results continue due to the impact of AR intervention.

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Appendix

Appendix 1 Stereotyped behavior scale it presents the data collection scale, which is divided into two parts: the responder profile and the assessment of the degree of stereotyped behavior.

Part I: Profile of Respondents.

Directions: Please fill out the information requested. Rest assured that your identity will be kept confidential.

Name: (Optional) ----------

Age: ----------

Gender:----------

Part II: Assessment of the level of stereotypical behavior of a child with autism spectrum disorder and its severity. Please use the following scale to describe the level of stereotypical behavior in a child with autism spectrum disorder.
Does not apply 2. Sometimes applies 3. Always applies

Table 1. Research instrument on stereotypical behavior

	Items	1	2	3
1	He exhibits compulsive behaviors, such as spinning several times before entering a room.	1	2	3
2	He stares with an unnatural gaze, such as looking at objects or people out of the corner of his eyes.	1	2	3
3	He carries unusual objects, such as plastic animal figurines.	1	2	3
4	He insists on following a specific routine, except for a sleep routine, such as arranging furniture in a particular way.	1	2	3
5	He excessively focuses on non-functional parts of objects, such as fixing car wheels.	1	2	3
6	He has unusual verbal rituals, such as asking others to say things in a specific manner.	1	2	3
7	He demonstrates excessive interest in certain things, such as being preoccupied with colors.	1	2	3
8	He experiences abnormal sensory manifestations, such as having a high pain tolerance.	1	2	3
9	He exhibits unusual responses to sensory inputs, such as being fascinated by bright lights.	1	2	3
10	He becomes preoccupied with the texture of objects, such as being engrossed by fabrics or textures.	1	2	3
11	He uses objects in a repetitive and ritualistic manner, such as repeatedly opening and closing doors or turning lights on and off.	1	2	3
12	He demonstrates delayed and echolalic speech, such as repeating phrases and words like a parrot.	1	2	3
13	He repeatedly asks about a specific topic, such as constantly inquiring about the weather.	1	2	3
14	He demonstrates atypical body postures, such as walking on tiptoes.	1	2	3
15	He shows intense fascination and fixation with observing the movement of objects, such as watching an electric fan while it is running.	1	2	3
16	He engages in repetitive activities that do not involve the use of specific objects, such as finger-snapping or teeth-grinding.	1	2	3
17	He produces non-purposeful, strange sounds, such as excessive teeth grinding.	1	2	3
18	He exhibits excessive rigidity in behavior and thinking, such as being self-centered and solely focused on satisfying his desires and needs.	1	2	3
19	He performs stereotypical movements involving the whole body, such as flapping, clapping, or shaking his head.	1	2	3
20	He engages in repetitive activities that involve the use of specific objects, such as tearing paper into small pieces.	1	2	3
21	He repeats unusual fears, such as being afraid of the presence of hair clippers, nail clippers, or toothbrushes.	1	2	3
22	He consistently performs repetitive movements during play, such as repeatedly placing his hands on his ears.	1	2	3
23	He repeats activities with a specific routine, such as performing certain rituals before going to sleep.	1	2	3
24	He exhibits excessive resistance to change, such as finding it difficult to transition from one activity to another.	1	2	3