JHWCR JOURNAL OF HEALTH, WELLNESS AND COMMUNITY RESEARCH 3007-0570

https://doi.org/10.61919/5z055w39

Original Article

The Influence of Augmented Reality on Emotional Processing and Empathy in Children with Autism Spectrum Disorder (ASD)

Fatima[1], Muhammad Mohsin Shoukat[2], Aaron Anthony John[3], Muhammad Arif[4], Saba Naz[5], Muhammad Uzair Mazhar[6]

[1] SR Psychiatry, Jinnah Medical College & Jinnah Teaching Hospital, Peshawar, Pakistan
[2] Consultant Pediatrician, THQ Hospital Hasilpur, District Bahawalpur, Pakistan
[3] Occupational Therapist, Dar Ul Sukun, Karachi, Pakistan. ORCID: 0009-0006-2404-5264
[4] Assistant Professor, Bolan Medical College, Quetta, Pakistan
[5] Riphah College of Nursing, Riphah International University, Islamabad, Pakistan. ORCID: 0009-0000-9991-2592
[6] King Edward Medical University/Mayo Hospital, Lahore, Pakistan. ORCID: 0009-0004-0711-0883

***Corresponding author: Saba Naz, sabaasim184@gmail.com**

"Cite this Article" Received: 09 April 2026; **Accepted**: 03 May 2026; **Published**: 23 May 2026

Author Contributions: Concept: F; Design: MMS; Data Collection: AAJ and MA; Analysis: SN; Drafting: MUM. **Ethical Approval** was obtained by the Respective Institution. **Informed Consent**: Written informed consent was obtained from all participants; **Conflict of Interest**: The authors declare no conflict of interest. **Funding**: No external funding; **Data Availability**: Available from the corresponding author on reasonable request; **Acknowledgments**: N/A.

ABSTRACT

Background: Children with autism spectrum disorder frequently experience difficulty recognizing facial expressions, interpreting emotional cues, and responding appropriately to social situations, which can affect communication, classroom participation, family interaction, and peer relationships. Augmented reality may support emotional learning by providing structured, visual, interactive, and repeated practice within a therapist-guided environment. **Objective:** To evaluate the influence of augmented reality-based emotional training on emotional recognition, empathy response, and social interaction among children with autism spectrum disorder in Peshawar, Pakistan. **Methods:** A controlled pre-test and post-test study was conducted among 40 children with diagnosed autism spectrum disorder aged 6–12 years. Participants were divided into an augmented reality plus routine therapy group and a routine therapy-only control group, with 20 children in each group. The intervention was delivered for eight weeks, with three sessions per week. Emotional recognition, empathy response, and social interaction were assessed before and after the intervention using structured tasks, therapist-rated assessment, observation, and caregiver feedback. **Results:** After eight weeks, the augmented reality group showed greater improvement than the control group across all outcomes. Emotional recognition improved from 13.4 ± 4.2 to 22.6 ± 3.8 in the augmented reality group compared with 13.1 ± 4.4 to 15.0 ± 4.2 in the control group. Empathy response increased from 16.7 ± 5.1 to 28.4 ± 4.6 compared with 16.2 ± 5.4 to 18.0 ± 5.2, while social interaction improved from 12.9 ± 4.0 to 21.8 ± 4.3 compared with 12.6 ± 4.1 to 14.3 ± 4.0. **Conclusion:** Augmented reality-based emotional training was associated with greater short-term improvement in emotional recognition, empathy-related responses, and social interaction among children with autism spectrum disorder when used alongside routine therapy. The findings support augmented reality as a practical adjunctive tool for structured socio-emotional learning in rehabilitation and special education settings. **Keywords:** Autism spectrum disorder; augmented reality; emotional recognition; empathy response; social interaction; children; Peshawar; Pakistan.

INTRODUCTION

Autism spectrum disorder is a neurodevelopmental condition characterized by persistent difficulties in social communication, social interaction, restricted or repetitive patterns of behaviour, and atypical sensory responses. The clinical presentation varies widely across children, with some demonstrating fluent speech but impaired social reciprocity, while others require substantial support for communication, adaptive behaviour, and daily functioning. Current global estimates indicate that autism

spectrum disorder affects approximately 1 in 100 children worldwide, although reported prevalence differs across regions because of variation in awareness, diagnostic practices, surveillance systems, and access to developmental services (1,2). Recent surveillance data from high-income settings have shown increasing identification of autism spectrum disorder among children, reflecting broader diagnostic recognition, improved screening, and expansion of service pathways (3). Despite these advances, children with autism spectrum disorder continue to experience significant barriers in emotional understanding, peer interaction, classroom participation, and family communication, particularly in settings where specialized developmental and rehabilitation services remain limited (4).

A central difficulty in autism spectrum disorder is impaired emotional processing, which refers to the ability to identify, interpret, label, and respond appropriately to emotional cues such as facial expressions, tone of voice, gestures, and social context. Many children with autism spectrum disorder have difficulty recognizing basic emotions, including sadness, anger, fear, surprise, and disgust, and these difficulties may become more pronounced when emotions are embedded within dynamic social situations rather than presented as isolated facial images. Evidence from systematic reviews and meta-analyses indicates that children and adolescents with autism spectrum disorder often perform less accurately than typically developing peers on facial emotion recognition tasks, although the magnitude of impairment varies according to task characteristics, developmental level, language ability, and cognitive profile (5,6). These emotional processing difficulties can affect reciprocal communication, friendship formation, classroom adjustment, and adaptive social behaviour, making them clinically important targets for intervention.

Empathy-related functioning is also an important component of social development in children with autism spectrum disorder. Empathy is multidimensional and includes both cognitive empathy, which involves understanding another person's thoughts or feelings, and affective empathy, which involves sharing or responding emotionally to another person's experience. Research suggests that children with autism spectrum disorder may show greater difficulty with cognitive aspects of empathy and social inference than with emotional concern itself, indicating that empathy should not be interpreted as absent but rather as differently expressed and often constrained by challenges in reading social cues (7). This distinction is important for intervention design because therapeutic goals should not aim to force neurotypical social behaviour, but rather to support children in recognizing emotional signals, understanding simple social situations, and developing practical response strategies in a respectful, structured, and developmentally appropriate manner.

Traditional interventions for children with autism spectrum disorder include behavioural, educational, communication-based, occupational therapy, speech therapy, parent-mediated, and social skills approaches. These interventions may improve communication, adaptive behaviour, social engagement, and functional participation when delivered consistently and individualized to the child's needs (8,9). However, implementation often requires trained professionals, repeated sessions, caregiver involvement, financial resources, and access to specialized services. In low- and middle-income countries, including Pakistan, families may face delayed diagnosis, limited availability of trained therapists, school exclusion, social stigma, caregiver stress, and financial strain. Local studies from Pakistan have highlighted gaps in autism awareness among parents and healthcare professionals, caregiver burden, and difficulties in accessing structured services for children with autism spectrum disorder (10,11). In Peshawar and similar settings, these barriers create a need for supportive, low-cost, culturally adaptable interventions that can be integrated into routine therapy and home-based practice.

Augmented reality is an emerging technology-based approach that may address some of these intervention challenges by combining real-world environments with digital visual cues, animations, sounds, labels, prompts, and interactive tasks. Unlike fully immersive virtual reality, augmented reality allows children to remain connected with the therapist, caregiver, classroom, or therapy room while receiving structured digital support. This feature may be particularly useful for children with autism spectrum disorder because many benefit from visual learning, repetition, predictability, immediate

feedback, and reduced ambiguity in social situations. Augmented reality can present facial expressions, emotion labels, social stories, role-play scenarios, and stepwise prompts in an engaging format, potentially helping children practise emotional recognition and empathy-related responses before applying them in real-life interactions (12,13).

Previous studies have explored augmented reality and related technology-supported interventions for children and adolescents with autism spectrum disorder, including applications targeting pretend play, attention, social communication, facial cue recognition, emotional expression, and socio-emotional coaching. Augmented reality-based self-facial modelling has been reported to support emotional expression and social skills, while augmented reality video-modelling storybooks have been used to teach nonverbal facial cues and emotion recognition. Smartglasses-based systems have also been investigated for social communication coaching, gaze-based emotion recognition, and socio-emotional learning in children with autism spectrum disorder (14). Systematic reviews suggest that augmented reality interventions show promising effects on social interaction, attention, communication, learning, and emotional skills; however, the existing evidence remains limited by small samples, short intervention periods, heterogeneous outcome measures, limited follow-up, and relatively few controlled experimental studies (12,15).

The current evidence gap is especially important in Pakistan, where most autism-related research has focused on awareness, parental stress, caregiver burden, healthcare knowledge, or genetic risk rather than directly testing culturally adapted therapeutic interventions for children with autism spectrum disorder. There is limited experimental evidence on whether augmented reality-based emotional training can improve emotional processing, empathy-related behaviour, and social interaction among Pakistani children with autism spectrum disorder. This gap is clinically relevant because digital tools that are low-cost, visually engaging, therapist-guided, and adaptable to Urdu or Pashto language support may improve access to structured emotional learning in rehabilitation centres, special education settings, and home programmes.

Therefore, the present study was designed to evaluate the influence of augmented reality-based emotional training on emotional processing and empathy-related social behaviour among children with autism spectrum disorder aged 6–12 years in Peshawar, Pakistan. Using a pre-test and post-test controlled design, the study compared children receiving augmented reality-based emotional training in addition to routine therapy with children receiving routine therapy alone. The primary focus was to determine whether repeated augmented reality-supported activities could improve recognition of basic emotions, understanding of simple social situations, empathy-related responses, and observed social interaction. The study was based on the hypothesis that children receiving augmented reality-based emotional training plus routine therapy would demonstrate greater improvement in emotional recognition, empathy response, and social interaction than children receiving routine therapy alone.

MATERIALS AND METHODS

This study was conducted as a controlled pre-test and post-test experimental study to evaluate the effect of augmented reality-based emotional training on emotional processing, empathy-related responses, and social interaction among children diagnosed with autism spectrum disorder. The study was carried out in selected autism rehabilitation centres, occupational therapy clinics, and special education settings in Peshawar, Pakistan, over a four-month period. A controlled design was selected to compare changes over time between children who received augmented reality-based emotional training in addition to routine therapy and children who continued routine therapy alone.

The study population consisted of children with a confirmed diagnosis of autism spectrum disorder who were living in Peshawar and receiving therapy or rehabilitation services at participating centres. Children of both genders were eligible for inclusion if they were between 6 and 12 years of age, had a confirmed diagnosis of autism spectrum disorder made by a paediatrician, psychiatrist, psychologist, or

developmental specialist, were able to follow simple one-step visual or verbal instructions with minimal support, could sit for at least 10 to 15 minutes during a structured activity, and had parental or guardian consent for participation. Children were excluded if they had severe visual or hearing impairment that could interfere with augmented reality-based tasks, uncontrolled epilepsy, severe aggressive behaviour that prevented safe participation, serious intellectual disability limiting engagement with the intervention, medical instability, or previous exposure to structured augmented reality-based emotional training within the preceding six months (4).

Participants were selected through purposive sampling from eligible children attending the selected centres and clinics. After baseline assessment, 40 children were included and divided into two groups of 20 participants each. The experimental group received augmented reality-based emotional processing training in addition to their ongoing routine therapy, while the control group continued routine therapy only. The groups were kept comparable as far as possible with respect to age, gender, school status, autism severity features, and previous therapy history. Routine therapy included services already being received by the children, such as occupational therapy, speech therapy, behavioural therapy, or special education support, and this therapy continued during the study period.

Data were collected using a structured demographic form, a facial emotion recognition task, a therapist-rated empathy and social response checklist, and structured observation of social interaction during therapy-based activities. The demographic form recorded age, gender, school status, birth order, family type, diagnostic history, previous therapy exposure, and screen exposure. Emotional processing was assessed through a facial emotion recognition task in which children were shown different facial expressions and asked to identify the emotion either verbally or by pointing to the correct emotion card. The emotions assessed included happiness, sadness, anger, fear, surprise, and calmness. Scores were assigned according to correct identification of the presented emotions. Empathy-related behaviour was assessed using a therapist-rated checklist that included responses such as recognizing sadness or anger in another person, responding when another person appeared upset, sharing attention, showing concern, and responding appropriately to short social stories. Caregiver feedback was also obtained to document observed behavioural changes in home settings. Social interaction was assessed through direct observation of eye contact, joint attention, turn-taking, response to name, imitation, participation in shared activity, and response to therapist prompts.

All baseline assessments were performed individually in a quiet therapy room before the start of the intervention. The assessment room was arranged to minimize sensory distraction, with low noise, adequate lighting, appropriate seating, and limited visual clutter. The same assessment procedures were used at baseline and after completion of the eight-week intervention period to maintain consistency in measurement. Children were assessed under similar environmental conditions at both time points, and scoring was performed according to the same criteria used during the baseline evaluation.

The experimental intervention was delivered for eight weeks, with three sessions per week. Each session lasted approximately 30 to 40 minutes, depending on the child's attention span, tolerance, and behavioural state on the day of the session. Sessions were conducted by a trained occupational therapist or rehabilitation professional. A tablet-based augmented reality application was used to present animated facial expressions, emotion labels, short social stories, role-play situations, and picture-based emotion tasks. The child sat with the therapist during the session, and caregivers were allowed to observe selected sessions so that similar activities could be reinforced during home practice.

Each intervention session began with a brief warm-up activity using simple emotion cards. The therapist asked the child to name, match, or point to the target emotion before starting the augmented reality task. During the augmented reality activity, the child viewed animated emotional expressions and short social situations on the tablet. The therapist provided structured prompts using simple questions such as asking how the character was feeling, why the character might feel that way, what response would be appropriate, and whether the child could imitate the facial expression. Positive reinforcement was

provided after correct responses or meaningful attempts, including verbal praise, clapping, smiley stickers, or a short preferred activity. Sessions were adjusted according to the child's sensory tolerance and attention level, and breaks were provided when the child became tired, distressed, or overstimulated.

The intervention progressed in stages across the eight-week period. During the first two weeks, the focus was on recognition of basic emotions, including happiness, sadness, anger, fear, surprise, and calmness. During weeks three and four, children practised matching emotions with simple social situations, such as identifying sadness after a toy was broken or recognizing happiness during play. During weeks five and six, children practised simple empathy-related responses, including helping, saying sorry, asking whether someone was okay, sharing, or approaching a person who appeared upset. During the final two weeks, children practised applying emotional recognition and empathy-related responses in short therapist-guided role-play activities. The control group received routine therapy only and did not participate in augmented reality-based emotional training during the study period.

The main study outcomes were emotional recognition score, empathy response score, and social interaction score. Emotional recognition referred to the child's ability to correctly identify basic emotional expressions. Empathy response referred to the child's ability to recognize and respond to another person's emotional state during checklist-based and story-based tasks. Social interaction referred to observable participation in shared activity, including attention, response to name, turn-taking, imitation, and therapist-directed interaction. The primary comparison was the change in these outcome scores from baseline to post-intervention between the experimental and control groups.

Several procedural steps were used to improve consistency and reduce measurement variability. Assessments were conducted in a low-distraction therapy environment using the same assessment approach before and after the intervention. The same outcome domains were measured at both time points. Both groups continued their existing routine therapy, and previous therapy history was recorded at baseline. Children in the experimental group received a structured intervention schedule with fixed frequency and duration across eight weeks. Therapy sessions followed a staged progression from basic emotion recognition to social situation interpretation, empathy response practice, and guided role-play application. Sessions were shortened or paused when a child showed signs of fatigue, distress, or sensory overload, allowing participation to remain safe and child-centered.

Data were entered and analysed using SPSS version 26. Frequencies and percentages were calculated for categorical variables, including gender, age group, school status, autism severity features, and therapy history. Means and standard deviations were calculated for continuous variables, including age and outcome scores. Baseline characteristics were compared between the experimental and control groups to assess group comparability before the intervention. Pre-test and post-test scores were compared within each group for emotional recognition, empathy response, and social interaction. Post-intervention differences and changes from baseline were used to evaluate whether improvement was greater in the experimental group than in the control group. A p-value of less than 0.05 was considered statistically significant.

Ethical permission was obtained from the concerned institution before data collection. Written informed consent was obtained from parents or guardians before enrolment. Children were provided a simple verbal explanation according to their level of understanding. Participation was voluntary, and parents or guardians were informed that they could withdraw their child at any stage without affecting routine therapy services. Confidentiality was maintained by assigning codes to participants and avoiding the use of names in the data sheet. The augmented reality activities were non-invasive, child-friendly, and conducted under professional supervision. Sessions were stopped, shortened, or paused if a child became distressed, tired, or overstimulated.

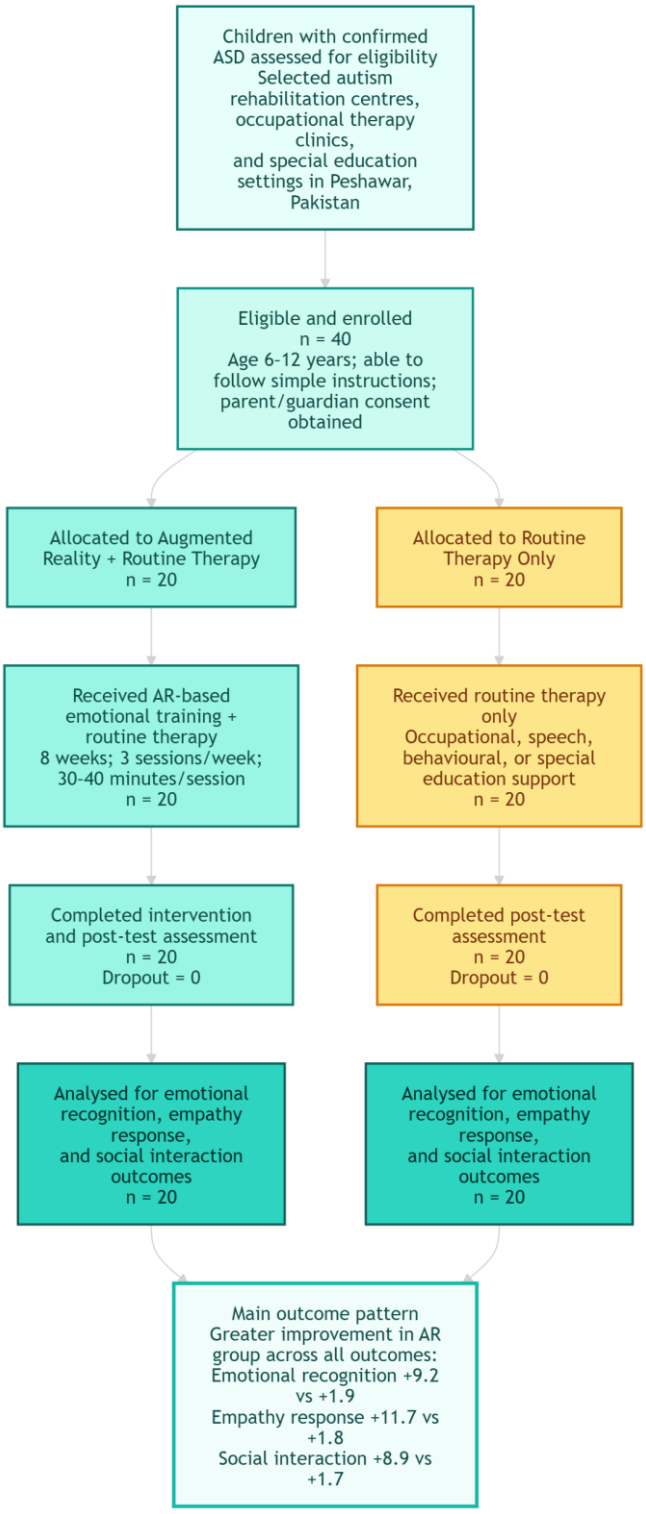

Figure 1. CONSORT Flow Diagram of Participant Allocation, Follow-Up, and Analysis in the Augmented Reality Intervention Study

RESULTS

A total of 40 children with autism spectrum disorder completed the study, with 20 participants in the augmented reality plus routine therapy group and 20 participants in the routine therapy-only group. No participant dropout was reported during the intervention period. The mean age was similar between groups, with children in the augmented reality group having a mean age of 8.65 ± 1.76 years and children in the control group having a mean age of 8.80 ± 1.64 years. Boys represented the majority of participants in both groups, accounting for 75.0% of the augmented reality group and 70.0% of the control group.

Baseline distributions of age category, gender, school status, autism severity features, and regular therapy history were comparable between groups, with all reported p-values above 0.05.

Table 1. Baseline Demographic and Clinical Characteristics of Children with Autism Spectrum Disorder

Variable	Augmented Reality + Routine Therapy (n=20)	Routine Therapy Only (n=20)	p-value
Mean age, years	8.65 ± 1.76	8.80 ± 1.64	0.78
Boys	15 (75.0%)	14 (70.0%)	0.72
Girls	5 (25.0%)	6 (30.0%)	0.72
Age 6–8 years	11 (55.0%)	10 (50.0%)	0.75
Age 9–12 years	9 (45.0%)	10 (50.0%)	0.75
Attending special school	11 (55.0%)	10 (50.0%)	0.75
Attending mainstream school	4 (20.0%)	5 (25.0%)	0.70
Not attending school	5 (25.0%)	5 (25.0%)	1.00
Mild ASD features	5 (25.0%)	4 (20.0%)	0.70
Moderate ASD features	12 (60.0%)	13 (65.0%)	0.74
Severe ASD features	3 (15.0%)	3 (15.0%)	1.00
Receiving regular therapy	16 (80.0%)	15 (75.0%)	0.70

At baseline, emotional recognition scores were low and closely matched between groups. The augmented reality group had a baseline emotional recognition score of 13.4 ± 4.2, while the control group had a score of 13.1 ± 4.4. After eight weeks, the augmented reality group improved to 22.6 ± 3.8, representing a mean increase of 9.2 points, whereas the control group improved to 15.0 ± 4.2, representing a mean increase of 1.9 points.

The within-group change was statistically significant in the augmented reality group ($p<0.001$), while the change in the control group was not statistically significant ($p=0.081$). The absolute difference in mean improvement between groups was 7.3 points, favouring augmented reality-based training.

Empathy response showed the largest improvement among the three assessed outcomes. The augmented reality group increased from 16.7 ± 5.1 at baseline to 28.4 ± 4.6 after intervention, giving a mean gain of 11.7 points. In comparison, the control group increased from 16.2 ± 5.4 to 18.0 ± 5.2, giving a mean gain of 1.8 points. The within-group change was statistically significant in the augmented reality group ($p<0.001$), but not in the control group ($p=0.096$). The mean improvement advantage for the augmented reality group was 9.9 points, indicating that the greatest relative benefit of the intervention was observed in empathy-related response behaviour.

Social interaction scores also increased more prominently in the augmented reality group. The mean score increased from 12.9 ± 4.0 before intervention to 21.8 ± 4.3 after intervention, with a mean change of 8.9 points and a statistically significant within-group difference ($p<0.001$). In the control group, the mean score increased from 12.6 ± 4.1 to 14.3 ± 4.0, with a mean change of 1.7 points that was not statistically significant ($p=0.104$). The between-group difference in mean improvement was 7.2 points in favour of augmented reality-based training.

Table 2. Pre-Test and Post-Test Outcome Scores by Study Group

Outcome Variable	Group	Pre-Test Mean ± SD	Post-Test Mean ± SD	Mean Change	Within-Group p-value	Difference in Mean Change Favoring AR
Emotional recognition score	Augmented reality + routine therapy	13.4 ± 4.2	22.6 ± 3.8	9.2	<0.001	7.3
	Routine therapy only	13.1 ± 4.4	15.0 ± 4.2	1.9	0.081	—
Empathy response score	Augmented reality + routine therapy	16.7 ± 5.1	28.4 ± 4.6	11.7	<0.001	9.9
	Routine therapy only	16.2 ± 5.4	18.0 ± 5.2	1.8	0.096	—
Social interaction score	Augmented reality + routine therapy	12.9 ± 4.0	21.8 ± 4.3	8.9	<0.001	7.2
	Routine therapy only	12.6 ± 4.1	14.3 ± 4.0	1.7	0.104	—

When the magnitude of improvement was compared across outcomes, the augmented reality group showed consistently larger gains than the control group. The greatest improvement was observed in empathy response, with an 11.7-point gain in the augmented reality group compared with a 1.8-point

gain in the control group. Emotional recognition improved by 9.2 points in the augmented reality group compared with 1.9 points in the control group, while social interaction improved by 8.9 points compared with 1.7 points, respectively. These changes indicate a consistent intervention-associated advantage across all measured emotional and social domains.

Table 3. Comparative Improvement Across Emotional and Social Outcomes

Outcome Variable	Mean Change in Augmented Reality Group	Mean Change in Control Group	Absolute Improvement Advantage
Emotional recognition score	9.2	1.9	7.3
Empathy response score	11.7	1.8	9.9
Social interaction score	8.9	1.7	7.2

Standardized post-intervention group differences also supported a large separation between the augmented reality and control groups after eight weeks. Based on post-test mean differences and pooled post-test standard deviations, the standardized mean difference was approximately 1.90 for emotional recognition, 2.12 for empathy response, and 1.81 for social interaction. These values indicate that the post-intervention differences were largest for empathy response, followed by emotional recognition and social interaction.

Table 4. Post-Intervention Between-Group Differences and Standardized Effect Estimates

Outcome Variable	Post-Test Mean ± SD in Augmented Reality Group	Post-Test Mean ± SD in Control Group	Post-Test Mean Difference	Standardized Mean Difference
Emotional recognition score	22.6 ± 3.8	15.0 ± 4.2	7.6	1.90
Empathy response score	28.4 ± 4.6	18.0 ± 5.2	10.4	2.12
Social interaction score	21.8 ± 4.3	14.3 ± 4.0	7.5	1.81

During therapy observations, children in the augmented reality group appeared more engaged during screen-based interactive emotional learning than during conventional paper-based tasks. Several children showed increased attention to animated facial expressions, pointed toward the screen, attempted to imitate facial expressions, and responded to therapist prompts during guided emotional scenarios.

Improvement was not uniform across all participants; children with better sitting tolerance and moderate autism features appeared to show faster task engagement than children with more severe attention and communication difficulties. Caregiver feedback was consistent with the observed post-test improvements, with parents reporting increased recognition of happy and angry expressions in cartoons or family situations and small empathy-related behavior's such as approaching a crying sibling or looking toward a caregiver using a sad tone.

Overall, the results showed greater post-intervention improvement in emotional recognition, empathy response, and social interaction among children who received augmented reality-based emotional training combined with routine therapy compared with children who received routine therapy alone. The most pronounced gain was observed in empathy response, followed by emotional recognition and social interaction.

The findings indicate that repeated, visually guided, therapist-supported augmented reality activities were associated with clinically meaningful short-term improvement in emotional and social functioning among children with autism spectrum disorder.

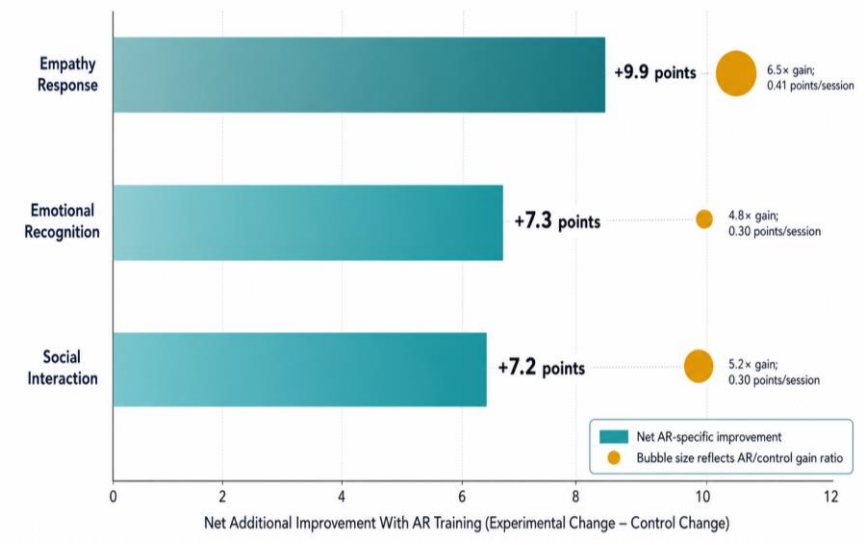

Figure 2. Outcome-Specific Added Benefit of Augmented Reality Emotional Training

The augmented reality group demonstrated a consistent added improvement advantage across all measured domains after 24 intervention sessions, with the largest net gain observed for empathy response at +9.9 points, corresponding to a 6.5-fold greater gain than routine therapy alone and an average added benefit of 0.41 points per session. Emotional recognition showed a +7.3-point added improvement, equivalent to a 4.8-fold greater gain and 0.30 points per session, while social interaction showed a similar +7.2-point added improvement with a 5.2-fold greater gain and 0.30 points per session. This gradient indicates that augmented reality-based emotional training was most strongly associated with empathy-related behavioral response, while also producing clinically meaningful advantages in emotion recognition and interactive social participation.

DISCUSSION

The present study found that children with autism spectrum disorder who received augmented reality-based emotional training in addition to routine therapy demonstrated greater short-term improvement in emotional recognition, empathy response, and social interaction than children who received routine therapy alone. The pattern of improvement was consistent across all assessed domains, with the largest mean gain observed in empathy response, followed by emotional recognition and social interaction. This finding suggests that augmented reality may provide more than a simple visual aid; when delivered through repeated, therapist-guided emotional scenarios, it may help children connect facial expressions with social meaning and appropriate behavioral responses. The observed improvement is clinically relevant because emotional processing and empathy-related responding are closely linked to daily communication, peer interaction, classroom participation, and family functioning in children with autism spectrum disorder.

The improvement in emotional recognition is consistent with previous evidence showing that children with autism spectrum disorder often experience difficulty identifying facial expressions, particularly when emotions are negative, subtle, or embedded in a social context. In the present study, baseline emotional recognition scores were low in both groups, indicating that the two groups entered the intervention with comparable difficulty in recognizing emotional cues. After eight weeks, the augmented reality group showed a larger gain than the control group, suggesting that animated, repeated, and visually structured emotional cues may have supported recognition of basic emotions more effectively than routine therapy alone. This finding aligns with systematic reviews reporting that augmented reality-based interventions can support social and cognitive learning in children and adolescents with autism spectrum disorder, although the strength of evidence varies across studies because of small samples, heterogeneous designs, and limited follow-up (16,17).

One possible explanation for this improvement is that augmented reality makes abstract emotional information more concrete and easier to practice. Emotional states such as sadness, fear, anger, and surprise may be difficult for children with autism spectrum disorder to interpret when they are presented only through natural social interaction, because real-life cues are often fast, subtle, and context-dependent. Augmented reality can slow down this process by presenting a clear facial expression, pairing it with a label, embedding it in a simple scenario, and allowing repeated practice under therapist guidance. This structured visual presentation may reduce ambiguity and increase the child's opportunity to associate facial expressions with social situations. Similar mechanisms have been described in augmented reality interventions targeting pretend play, facial cue learning, and social communication, where digital overlays and interactive prompts help children engage with concepts that may otherwise remain abstract or difficult to interpret (18,19).

The largest improvement was observed in empathy response, which increased more markedly in the augmented reality group than in the control group. This finding is important because empathy-related behaviour in autism spectrum disorder is often misunderstood. Difficulties in responding to another person's distress do not necessarily indicate lack of emotional concern; rather, they may reflect challenges in recognizing emotional cues, interpreting another person's mental or emotional state, and selecting an appropriate response. In the present study, children practiced simple empathic responses such as looking toward a sad person, saying "sorry," asking whether someone was okay, helping, and sharing during guided augmented reality scenarios. These activities may have supported cognitive empathy and response planning by teaching children what an emotional situation means and what action may be socially appropriate. This interpretation is consistent with multidimensional models of empathy in autism spectrum disorder, which distinguish cognitive empathy from affective concern and emphasize that autistic children may require structured support to translate emotional understanding into observable social responses (20).

The improvement in social interaction also supports the potential role of augmented reality as an engaging therapeutic support tool. Children in the augmented reality group showed better participation in shared activities, attention to prompts, turn-taking, and response during therapist-guided tasks. These changes may be partly explained by increased motivation and task engagement. Many children with autism spectrum disorder respond well to predictable visual routines, interactive feedback, and repeated practice, and these features were built into the intervention. The use of animated facial expressions, sound, labels, and role-play scenarios may have increased attention and reduced avoidance compared with static paper-based emotional learning activities. Previous studies using augmented reality and smartglasses-based systems have similarly suggested that technology-supported socio-emotional coaching may improve engagement, attention, and social communication when used in a structured and supervised therapeutic setting (21,22).

The smaller improvement observed in the control group may reflect the continuing benefits of routine therapy, repeated exposure to assessment tasks, maturation, caregiver involvement, or increased familiarity with the therapy environment. However, the magnitude of change was consistently larger in the augmented reality group across emotional recognition, empathy response, and social interaction. This pattern suggests that augmented reality-based training may have provided an additional therapeutic advantage beyond routine therapy alone. Importantly, the intervention was delivered as an adjunct to existing therapy rather than as a replacement for therapist-led care. This distinction is clinically important because children with autism spectrum disorder often require individualized prompting, reinforcement, sensory regulation, and behavioural support during learning. The therapist's role in guiding attention, interpreting emotional content, reinforcing responses, and adjusting session demands likely contributed to the observed outcomes.

The findings also have relevance for the local context of Peshawar and similar low-resource settings in Pakistan. Families of children with autism spectrum disorder may face delayed diagnosis, limited access

to trained therapists, financial barriers, social stigma, and lack of structured home-based intervention resources. A tablet-based augmented reality programme may offer a practical supportive approach because it can present emotional learning activities in a standardized, engaging, and repeatable format. If adapted into culturally familiar scenarios and supported by Urdu or Pashto language prompts, augmented reality could be integrated into rehabilitation centres, special education settings, and caregiver-guided practice. Local acceptability is especially important because interventions are more likely to be used consistently when they are affordable, understandable, and compatible with family routines and available therapy services (23).

Although the results are promising, the findings should be interpreted within the methodological boundaries of the study design. The sample size was small, and participants were selected from selected rehabilitation and therapy settings, which may limit generalizability to all children with autism spectrum disorder in Pakistan. The intervention period was limited to eight weeks, and long-term maintenance of emotional recognition, empathy-related response, and social interaction skills was not assessed. Some outcomes were based on therapist observation and caregiver feedback, which may be influenced by observer expectation or familiarity with the child. In addition, children with better sitting tolerance and moderate autism features appeared to engage more rapidly with the intervention, suggesting that response to augmented reality training may vary according to attention span, communication ability, sensory profile, and baseline developmental functioning.

Another important consideration is that improvement in structured therapy tasks does not automatically ensure transfer to complex real-world social environments. Emotional learning in autism spectrum disorder often requires repeated practice across people, settings, and situations. A child may learn to identify sadness or anger on a tablet-based activity but may still need support to recognize the same emotion in a sibling, classmate, parent, or teacher during spontaneous interaction. Therefore, the clinical value of augmented reality may be greatest when digital emotional training is paired with therapist-led role-play, caregiver coaching, classroom reinforcement, and home-based practice. This combined approach can help bridge the gap between structured recognition tasks and functional social communication in daily life.

Overall, the study supports augmented reality-based emotional training as a promising adjunctive intervention for children with autism spectrum disorder. The strongest observed gain in empathy response suggests that repeated visual scenarios may help children not only identify emotions but also practise meaningful social responses. Improvements in emotional recognition and social interaction further indicate that augmented reality may strengthen multiple related domains of socio-emotional functioning. Within the local rehabilitation context, this approach appears especially useful when it is simple, structured, culturally adaptable, therapist-guided, and integrated with routine occupational therapy, speech therapy, behavioural therapy, and caregiver-supported practice.

CONCLUSION

This study concluded that augmented reality-based emotional training, when provided alongside routine therapy, was associated with greater improvement in emotional recognition, empathy response, and social interaction among children with autism spectrum disorder than routine therapy alone. The most pronounced improvement was observed in empathy-related responses, suggesting that structured augmented reality activities may help children connect emotional cues with appropriate social behaviours such as looking toward a distressed person, naming the emotion, asking whether someone is okay, or offering simple help. Improvements in emotional recognition and social interaction further indicate that visually guided, repetitive, and therapist-supported augmented reality tasks can strengthen multiple domains of socio-emotional functioning in children with autism spectrum disorder. In the context of Peshawar, where many families face limited access to specialized autism services, augmented reality may serve as a practical supportive tool for rehabilitation centres, special education settings, and

caregiver-guided home practice, particularly when adapted to local language, culture, and therapy routines. These findings support the use of augmented reality as an adjunct to, rather than a replacement for, occupational therapy, speech therapy, behavioural therapy, and parent-mediated intervention.

REFERENCES

1. Lord C, Elsabbagh M, Baird G, Veenstra-Vanderweele J. Autism spectrum disorder. Lancet. 2018;392(10146):508-520. doi:10.1016/S0140-6736(18)31129-2.

2. Zeidan J, Fombonne E, Scorah J, Ibrahim A, Durkin MS, Saxena S, et al. Global prevalence of autism: A systematic review update. Autism Res. 2022;15(5):778-790. doi:10.1002/aur.2696.

3. Maenner MJ, Warren Z, Williams AR, Amoakohene E, Bakian AV, Bilder DA, et al. Prevalence and characteristics of autism spectrum disorder among children aged 8 years — Autism and Developmental Disabilities Monitoring Network, 11 Sites, United States, 2020. MMWR Surveill Summ. 2023;72(2):1-14. doi:10.15585/mmwr.ss7202a1.

4. Hodges H, Fealko C, Soares N. Autism spectrum disorder: Definition, epidemiology, causes, and clinical evaluation. Transl Pediatr. 2020;9(Suppl 1):S55-S65. doi:10.21037/tp.2019.09.09.

5. Smith T, Iadarola S. Evidence base update for autism spectrum disorder. J Clin Child Adolesc Psychol. 2015;44(6):897-922. doi:10.1080/15374416.2015.1077448.

6. Wong C, Odom SL, Hume KA, Cox AW, Fettig A, Kucharczyk S, et al. Evidence-based practices for children, youth, and young adults with autism spectrum disorder: A comprehensive review. J Autism Dev Disord. 2015;45(7):1951-1966. doi:10.1007/s10803-014-2351-z.

7. Grynszpan O, Weiss PL, Perez-Diaz F, Gal E. Innovative technology-based interventions for autism spectrum disorders: A meta-analysis. Autism. 2014;18(4):346-361. doi:10.1177/1362361313476767.

8. Berenguer C, Baixauli I, Gómez S, Andrés MEP, De Stasio S. Exploring the impact of augmented reality in children and adolescents with autism spectrum disorder: A systematic review. Int J Environ Res Public Health. 2020;17(17):6143. doi:10.3390/ijerph17176143.

9. Khowaja K, Banire B, Al-Thani D, Sqalli MT, Aqle A, Shah A, et al. Augmented reality for learning of children and adolescents with autism spectrum disorder: A systematic review. IEEE Access. 2020;8:78779-78807. doi:10.1109/ACCESS.2020.2986608.

10. Dechsling A, Orm S, Kalandadze T, Sütterlin S, Øien RA, Shic F, et al. Virtual and augmented reality in social skills interventions for individuals with autism spectrum disorder: A scoping review. J Autism Dev Disord. 2022;52:4692-4707. doi:10.1007/s10803-021-05338-5.

11. Zhang M, Ding H, Naumceska M, Zhang Y. Virtual reality technology as an educational and intervention tool for children with autism spectrum disorder: Current perspectives and future directions. Behav Sci. 2022;12(5):138. doi:10.3390/bs12050138.

12. Bai Z, Blackwell AF, Coulouris G. Using augmented reality to elicit pretend play for children with autism. IEEE Trans Vis Comput Graph. 2015;21(5):598-610. doi:10.1109/TVCG.2014.2385092.

13. Chen CH, Lee IJ, Lin LY. Augmented reality-based self-facial modeling to promote the emotional expression and social skills of adolescents with autism spectrum disorders. Res Dev Disabil. 2015;36:396-403. doi:10.1016/j.ridd.2014.10.015.

14. Chen CH, Lee IJ, Lin LY. Augmented reality-based video-modeling storybook of nonverbal facial cues for children with autism spectrum disorder. Comput Human Behav. 2016;55:477-485. doi:10.1016/j.chb.2015.09.033.

15. Cihak DF, Moore EJ, Wright RE, McMahon DD, Gibbons MM, Smith CC. Evaluating augmented reality to complete a chain task for elementary students with autism. J Spec Educ Technol. 2016;31(2):99-108. doi:10.1177/0162643416651724.

16. Escobedo L, Tentori M, Quintana E, Favela J, Garcia-Rosas D. Using augmented reality to help children with autism stay focused. IEEE Pervasive Comput. 2014;13(1):38-46. doi:10.1109/MPRV.2014.19.

17. Lorenzo G, Gómez-Puerta M, Arráez-Vera G, Lorenzo-Lledó A. Preliminary study of augmented reality as an instrument for improvement of social skills in children with autism spectrum disorder. Educ Inf Technol. 2019;24:181-204. doi:10.1007/s10639-018-9768-5.

18. Liu R, Salisbury JP, Vahabzadeh A, Sahin NT. Feasibility of an autism-focused augmented reality smartglasses system for social communication and behavioral coaching. Front Pediatr. 2017;5:145. doi:10.3389/fped.2017.00145.

19. Vahabzadeh A, Keshav NU, Abdus-Sabur R, Huey K, Liu R, Sahin NT. Improved socio-emotional and behavioral functioning in students with autism following school-based smartglasses intervention. Behav Sci. 2018;8(10):85. doi:10.3390/bs8100085.

20. Sahin NT, Keshav NU, Salisbury JP, Vahabzadeh A. Second version of Google Glass as a wearable socio-affective aid: Positive school desirability, high usability, and theoretical framework in a sample of children with autism. JMIR Hum Factors. 2018;5(1):e1. doi:10.2196/humanfactors.8785.

21. Keshav NU, Vahabzadeh A, Abdus-Sabur R, Huey K, Salisbury JP, Liu R, et al. Longitudinal socio-emotional learning intervention for autism via smartglasses. Educ Sci. 2018;8(3):107. doi:10.3390/educsci8030107.

22. Nag A, Haber N, Voss C, Tamura S, Daniels J, Ma J, et al. Toward continuous social phenotyping: Analyzing gaze patterns in an emotion recognition task for children with autism through wearable smart glasses. J Med Internet Res. 2020;22(4):e13810. doi:10.2196/13810.

23. Yeung MK. A systematic review and meta-analysis of facial emotion recognition in autism spectrum disorder. Neurosci Biobehav Rev. 2022;133:104518. doi:10.1016/j.neubiorev.2021.104518.