

Evaluating the Comparative Effectiveness of Traditional and AI-Assisted Speech Therapy on Communication Outcomes in Children with Autism Spectrum Disorder

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ABSTRACT:

Communication impairments are major challenges for children with Autism Spectrum Disorder (ASD), affecting expressive language, receptive language, social interaction, and adaptive functioning. The growing need for accessible and individualized speech-language interventions has increased interest in artificial intelligence (AI)-assisted technologies as complementary clinical tools. This study compared the effectiveness of Traditional Speech Therapy (TST) and AI-Assisted Speech Therapy (AIST) in improving communication outcomes among children with ASD in Pakistan. A randomized controlled trial was conducted with 100 children aged 5–12 years. Participants were selected through purposive sampling from selected special education schools, autism rehabilitation centers, and speech therapy clinics, and were then randomly assigned to the TST group ($n = 50$) or AIST group ($n = 50$). Both groups received three 45-minute sessions per week for 12 weeks. Outcomes were assessed using the CCC-2, Vineland Communication Domain, ATEC Communication Subscale, and Therapist Observation Checklist. The AIST group showed significantly greater improvements in expressive and receptive language, social communication, eye contact, verbal initiation, turn-taking, and overall communication performance ($p < .001$). Large effect sizes (Cohen's $d = 1.14$ – 1.46) and ANCOVA findings confirmed the superiority of AIST after controlling for baseline ability. The findings support AI-assisted speech therapy as an evidence-based complement to conventional rehabilitation.

Keywords: Autism Spectrum Disorder, Artificial Intelligence, AI-Assisted Speech Therapy, Traditional Speech Therapy, Communication Outcomes, Speech-Language Pathology, Pakistan.

Introduction

Communication is a critical component of a child's development, and the development of communication skills is essential for social interaction, learning, and adapting to the environment. The problem with verbal and non-verbal communication is one of the most prominent and persistent difficulties in children with Autism Spectrum Disorder (ASD) that can impact expressive language, receptive language, social interaction, and adaptive functioning (Wetherby et al., 2007). If not addressed through timely intervention, these communication challenges can have a negative impact on academic achievement, peer relationships, and quality of life (Gilhuber, 2023). So the issue of communication interventions continues to be a major research and clinical priority in autism.

Early intervention has been shown to make a large difference in the communication of children with ASD. Joint attention, imitation, and symbolic play are considered to be the foundation of early development of language and social competence (Toth et al., 2006). Targeted communication interventions at early ages are more likely to result in functional language and adaptive social behavior compared to delayed intervention (Kasari et al., 2008). As a result, speech and language therapy is one of the most implemented strategies to facilitate children's communication development with ASD.

Though this is the exception, the typical treatment modality for communication problems related to ASD is traditional speech and language therapy provided by certified Speech-Language Pathologists (SLPs). These interventions tend to involve articulation, vocabulary development, receptive/expressive language, conversation skills, and pragmatic skills (Law et al., 2004). While conventional speech therapy has proven to be effective in enhancing communication outcomes, it is difficult to scale and implement, especially in low- and middle-income countries.

There is often limited access to trained professionals, financial resources, and geographical distance that limit children's access to regular therapeutic services (Gernsbacher, 2006). The issues are very relevant in Pakistan as the number of specialized autism services and qualified speech-language professionals are still not sufficient to address the growing demand for intervention services. Even with the need to access frequent therapy, many families face problems because of a shortage of trained therapists, the cost of therapy, and the distance from specialized centers. This makes it essential for innovative and scalable approaches of intervention to be created to supplement the current therapeutic services and enhance the provision of communication support for children with ASD (Arshad, 2023). Artificial Intelligence (AI) has created new opportunities for speech and language intervention in recent years. AI-based speech therapy tools integrate features like automatic speech recognition, machine learning algorithms, adaptive feedback systems, and gamified exercises to deliver personalized and engaging speech therapy experiences (Dadgar et al., 2025). These technologies can provide ongoing practice opportunities, real-time feedback on performance, and adapt intervention levels to the individual's progress. Of course, AI-supported systems could also provide structured communication support outside of the clinic, allowing for communication practice in the home and education setting (Attwell et al., 2022).

There is emerging evidence of potential improvement in engagement, motivation, and communication for children with ASD. There has been some evidence of higher rates of participation, lower anxiety during communication tasks, and better social interaction skills among individuals with ASD (Grynszpan et al., 2014; Ploog et al., 2013) with computer-assisted and technology-mediated interventions. Although there has been an increase in international interest in AI-assisted

therapy, there is yet little empirical research directly testing AI-assisted speech therapy against therapist-led therapy, especially in the context of developing countries. The current literature in Pakistan has mainly focused on individual communication interventions or descriptive studies of communication problems in autism, rather than comparisons between traditional and AI-supported therapeutic methods (Arshad, 2023). Hence, the research gap concerns the effectiveness of these intervention modalities relative to one another in Pakistan. In this regard, the present study compares the effectiveness of Traditional Speech Therapy (TST) with AI-Assisted Speech Therapy (AIST) on communication outcome of children with Autism Spectrum Disorder (ASD) in Pakistan. In a randomized controlled trial (RCT) design, the study investigates the differences between the two intervention approaches in language development, social communication, engagement, and overall communication performance. The results are anticipated to provide evidence for the role AI-assisted technologies could play in assisting communication intervention for children with ASD in the healthcare and educational context where resources are limited.

Research Gap

While traditional speech therapy and technology-assisted communication interventions have shown efficacy in enhancing communication abilities in children with Autism Spectrum Disorder (ASD), there is limited direct evidence comparing traditional therapist-led speech therapy with AI-assisted speech therapy. Earlier research has focused on these interventions separately, and there are few studies that have directly compared their efficacy through rigorous experimental designs (Dadgar et al., 2025; Grynszpan et al., 2014). Moreover, the evidence available comes largely from high-income countries, and its relevance to low- and middle-income countries is often questionable, as it is not always accessible to them for special speech and language services (Attwell et al., 2022). While a number of studies have been conducted in Pakistan that address individual intervention

strategies, communication difficulties, and the perspectives of caregivers, few direct comparisons have been made between traditional and AI-supported speech therapy approaches (Arshad, 2023). Thus, empirical evidence on the effectiveness of using AI-based speech therapy, in terms of communication outcomes, to match or exceed conventional speech therapy services in children with ASD is not available in Pakistan. To address this, the present study explores the effectiveness of AI-Assisted Speech Therapy (AIST) vs Traditional Speech Therapy (TST) for communication outcome in children with ASD in Pakistan through a randomized controlled trial (RCT).

Research Objectives

The primary objective of the present study is to compare the effectiveness of Traditional Speech Therapy (TST) and AI-Assisted Speech Therapy (AIST) in enhancing communication abilities of children with Autism Spectrum Disorder (ASD) in Pakistan.

1. To compare the effectiveness of Traditional Speech Therapy (TST) and AI-Assisted Speech Therapy (AIST) in improving communication outcomes, including expressive language, receptive language, social communication, and therapist-observed communication behaviors among children with Autism Spectrum Disorder.
2. To compare post-intervention communication outcomes between children receiving Traditional Speech Therapy and those receiving AI-Assisted Speech Therapy using standardized communication assessments and therapist observation measures.
3. To examine whether differences in communication outcomes between the two intervention groups remain significant after controlling for baseline communication performance.
4. To determine the practical significance of Traditional Speech Therapy and AI-Assisted Speech Therapy by estimating the magnitude of intervention effects using Cohen's *d* effect sizes.

5. To evaluate the effectiveness of AI-Assisted Speech Therapy as an intervention for improving communication outcomes among children with Autism Spectrum Disorder within the Pakistani healthcare and educational context.

Research Hypotheses

H1: Children receiving AI-Assisted Speech Therapy will demonstrate significantly greater improvements in communication outcomes than children receiving Traditional Speech Therapy.

Theoretical Framework

The current study is based on two complementary theories: Vygotsky's Zone of Proximal Development (ZPD) and the Technology Acceptance Model (TAM). These frameworks offer a theoretical foundation for the acquisition of communication skills and also for the theoretical consideration of the potential of technology-assisted interventions to support therapeutic outcomes for children with Autism Spectrum Disorder (ASD).

Vygotsky's Zone of Proximal Development (ZPD)

The Zone of Proximal Development (ZPD) theory by Vygotsky suggests that learning is most effective when a person is assisted in carrying out an activity that goes beyond what he or she can independently complete, but is within the range of possibility with proper guidance and assistance (Vygotsky, 1978). In speech and language intervention, therapists offer structured support, feedback, and scaffolding for children to work towards increasingly advanced communication skills. This is especially important for children with ASD who may need systematic directions to develop expressive language, receptive language, social communication and pragmatic skills. Studies have shown that having a program that focuses on guided participation, joint attention, and social interaction can make a tremendous difference for the communication development of children with ASD (Kasari et al., 2008; Toth et al., 2006). Traditional speech therapy is based on the principles of ZPD, in that the speech-language pathologists continually modify activities based on the child's communication

skills and developmental needs in direct interactions between therapist and child. Likewise, AI-powered speech therapy tools can implement the ZPD principles by dynamically varying the complexity of tasks based on the child's responses. AI-driven systems offer structured scaffolding through real-time feedback, customized learning paths, and progressive skill development, which fosters communication development while ensuring a suitable level of challenge. Hence, ZPD becomes helpful to understand how communication development can be promoted in children with ASD using both TST and AIST.

Technology Acceptance Model (TAM)

The Technology Acceptance Model (TAM) proposed by Davis (1989) captures the acceptance and use of technology from two factors: Perceived Usefulness and Perceived Ease of Use. TAM suggests that if the user finds the technological system beneficial and easy to use, he or she is more likely to use and accept it. TAM was initially proposed for use with technologies for adults, but has been extensively used with educational and healthcare technologies to help understand the engagement and adoption of technologies. Technology-based learning environments can also offer children with ASD structured, predictable, and visually stimulating learning experiences that are in keeping with the learning styles of many children with ASD (Ploog et al., 2013). Gamification, interactive rewards, visual feedback, and adaptive challenges may boost motivation, participation, and extended engagement in therapeutic activities. AI-powered speech therapy apps integrate many of these capabilities, which can boost children's enthusiasm for engaging in communication activities and make it easier to ensure regular therapy participation. Higher engagement can then lead to better communication results, due to additional practice opportunities and by reinforcing learned skills. This means that TAM can provide some insight into the potential for greater participation and therapeutic effects of speech therapy with the help of AI compared to conventional approaches to intervention.

Conceptual framework

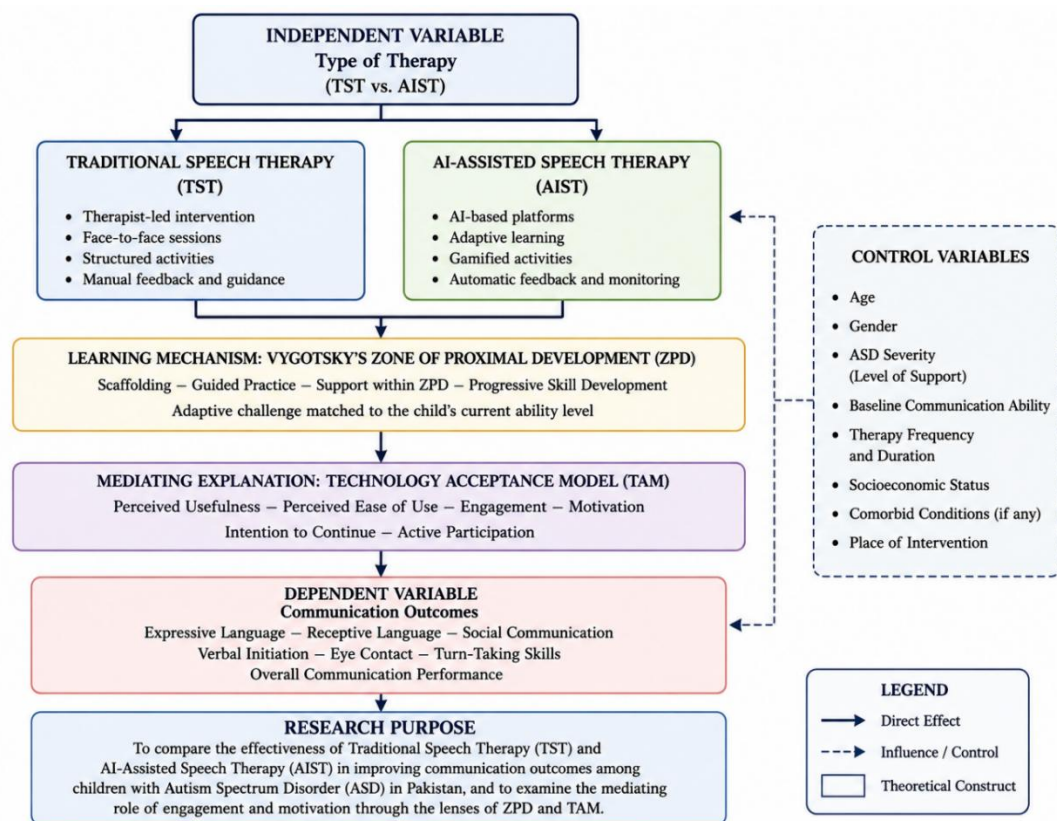


Figure 1: Conceptual Framework of the Study

Conceptual Relationship

Figure 1 illustrates the conceptual framework underpinning the present study. The independent variable is the type of speech therapy that is being used, which is Traditional Speech Therapy (TST) and AI-Assisted Speech Therapy (AIST). Both interventions offer the structured scaffolding that is needed for communication development, based on Vygotsky's Zone of Proximal Development (ZPD). This article introduces the Technology Acceptance Model (TAM), which describes the positive impacts of perceived usefulness, ease of use, engagement, and motivation on children's participation in AI-assisted interventions. The dependent variables include the communication outcome, expressive language, receptive language, social communication, verbal initiation, eye contact, turn-taking skills, and overall communication outcome. To minimize the potential confounding effects, the following variables were considered as covariates: baseline communication ability, age, gender, severity of ASD, frequency and

duration of therapy, socioeconomic status, presence of comorbid conditions, and place of intervention. Altogether, the framework visualizes the theoretical processes by which we can think of AI-assisted and traditional speech therapy to affect the communication outcomes for children with Autism Spectrum Disorder in Pakistan.

Literature Review

Communication Deficits and Intervention Needs in Children with Autism Spectrum Disorder

Communication problems are also a major part of the diagnostic criteria for Autism Spectrum Disorder (ASD). Children with ASD typically have challenges with verbal expression, receptive language, social interaction, non-verbal communication and pragmatic language use. The Diagnostic and Statistical Manual of Mental Disorders, DSM-5-TR, defines ASD as having persistent deficits in social communication and social interaction in a variety of settings,

restricted and repetitive patterns of behavior (American Psychiatric Association, 2022). The communication problems can hinder a child's ability to communicate their needs, see instructions, join in with class activities, make friends and cope independently in daily activities. Early social communication skills are important predictors of later language development. Toth et al. (2006) reported that initial instances of joint attention, imitation and symbolic play are highly correlated with subsequent communication in children with ASD. Likewise, Wetherby et al., (2007) found that early social communication profiles can be useful in recognizing children at risk for ongoing language and developmental problems. Children with ASD might have limited eye contact, not respond to their name being called, fail to take turns when talking, have fewer gestures, and struggle to begin conversations. If these early deficits are left untreated, it can impact on the later language development of expression and comprehension. Communication profiles in ASD are highly heterogeneous. Some children never develop any verbal skills; others learn words and sentence patterns but have difficulty with the social aspects of language, conversation and pragmatic language. Kjelgaard and Tager-Flusberg (2001) reported that language abilities varied significantly from one child with autism to another, and thus the communication intervention needed for each child cannot be standardized. This diversity underscores the need for flexible therapeutic strategies that include working on articulation, vocabulary, comprehension, social communication and functional communication based on the child's level of development. Early and evidence-based communication intervention is thus highly recognized. Rogers and Dawson (2010) highlighted the importance of intensive early intervention in helping young children with ASD develop socially and communicate. Likewise, Schreibman et al. (2015) claimed naturalistic developmental behavioral interventions are effective since they integrate structured teaching with child-centered interactions. Speech therapy in this context continues to be an integral part of functional communication, social inclusion and reduction of social barriers.

Traditional Speech Therapy for Children with ASD

The traditional Speech Therapy (TST) approach is still one of the most common strategies used to enhance outcomes in communication skills for children with ASD. Typically provided by qualified Speech-Language Pathologists and targets expressive language, receptive language, articulation, vocabulary development, social communication, and pragmatic language skills. When intervention is structured, consistent, and professionally guided, the communication outcome with children with developmental language difficulties can be improved through speech and language therapy, as reported by Law et al. (2004). Traditional therapy in ASD includes modelling, prompting, imitating, reinforcing, using pictures for communication, storytelling, turn-taking, and conversation practice. Therapist-led intervention offers several clinical benefits. The therapist can observe, increase or decrease the difficulty, give immediate feedback and tailor strategies to the child's needs. Kasari et al., (2008) reported positive effects of the interventions that focused on joint attention and play skills on language outcomes for children with autism. The results have significance as joint attention is strongly tied to social learning and later language development. Likewise, Paul (2008) highlighted that communication intervention for children with ASD should focus on language structure and social communication functions. This is also supported by traditional approaches by facilitating direct human contact. Eye contact, turn-taking, verbal initiation, and responses can be difficult for children with ASD to learn due to the need for structured support. Koegel et al. (2012) described that interventions can be implemented in natural interaction, which can enhance motivation and communication use. This is where therapist-led intervention can be useful since children can engage in communication in meaningful social settings. The effectiveness of traditional therapy is related, however, to treatment intensity, therapist skills, family involvement and regularity of attendance. Although very important, traditional speech therapy has many constraints in low- and middle-

income countries. Gernsbacher (2006) pointed out that service availability, service cost, and professional shortages can hinder access to autism intervention services. Many families in Pakistan encounter other difficulties like the availability of fewer autism centers, cost of therapy, scarcity of trained Speech-Language Pathologists, geographical issues, and lack of awareness about early intervention. Rahbar et al. (2011) pointed out that Pakistan needs better services and awareness about autism. These barriers affect therapy continuity and make it challenging for children to receive sufficient intensity of intervention for meaningful progress.

AI-Assisted Speech Therapy and Emerging Technologies

Advances in digital health and AI have opened up new opportunities for speech and language intervention. The AI-Assisted Speech Therapy (AIST) component can feature automatic speech recognition, adaptive learning systems, real-time feedback, gamified therapy exercises, progress monitoring, and individualized therapy tasks. Children may benefit from using these tools to help with repeated practice, visual feedback, and motivating activities. Predictable and structured digital environments may be particularly helpful for children with ASD as many children benefit from visual structures and interactive learning. There are promising results for technology-assisted interventions available for children diagnosed with ASD. Grynspan, et al. (2014) completed a meta-analysis and determined that innovative technology-based interventions can increase learning and social communication outcomes for people with ASD. Ploog et al. (2013) also noted that computer-based technologies could be used to help assist with social skills training, as they offer structure, repetition, and a visual element. The features are very pertinent to the children with ASD as they need repeated exposure and repetitive reinforcement to build communication skills. AI-driven platforms can also enhance engagement and motivation. Children's attention is maintained with the use of reward systems, levels, animation and instant feedback many digital tools offer in communication tasks. Parsons and Cobb

(2011) suggested that technology-based learning environment may offer a protected and supervised environment for autistic children to practice social and communication skills. Likewise, Bölte et al. (2010) reported that computer-based interventions can be helpful, provided they are well designed and clinically monitored. These results indicate that an AI-supported therapy could augment communication intervention in the future by providing more practice opportunities and increasing the motivation for therapy. One more benefit of AI-backed treatment is that it can help to expand therapy past the clinical setting. Digital tools can be used to assist the home practice, to involve parents, and to help with continuity between therapeutic sessions. This is particularly crucial in Pakistan where children might not have access to regular speech therapy services. Telepractice and technology-based intervention can be used to fill gaps in service delivery, providing opportunities for children to practice communication skills with guidance remotely or indirectly from a professional. But AI-assisted therapy shouldn't be a substitute for therapists. Rather, it is best used as a complementary tool under the supervision of a professional to make sure that interventions are developmentally appropriate and clinically meaningful. There are also significant issues to consider. Sometimes, AI tools might not understand local accents, multilingual speech or culturally specific ways of communicating. Pakistan is linguistically diverse with Urdu, Punjabi, Pashto, Sindhi, Balochi and regional dialects. AI systems that are predominantly trained on English-speaking or Western populations might not be as accurate for children from Pakistan. Other significant issues are data privacy, screen time control, parent training, cost and clinical validation. Thus, the use of AI in speech therapy should be carefully evaluated in the local context before it can be recommended on a large scale.

Comparative Studies of Traditional and Technology-Assisted Interventions

While both traditional speech therapy and technology-assisted interventions provide positive results, comparisons between the two are

still limited. Binger and Light (2007) determined that communication development of children using AAC could be enhanced using augmentative and alternative communication (AAC) as an aided language model. Mirenda (2003) also stated that within the context of natural environments, AAC and technology-supported communication systems can also improve functional communication for children with autism. While the research demonstrates that technology can be used to facilitate communication, it does not provide a clear answer as to whether the AI-driven speech therapy is more effective than therapist-led speech therapy. Comparative evidence is still in the process of development. Ramdoss et al. (2011) conducted a review of computer-based interventions for individuals diagnosed with ASD and found that while some interventions have shown to help with communication and academic abilities, methodological quality was not consistent across studies. Likewise, Kagohara et al. (2013) determined that handheld technology like iPods and tablets has the potential to assist communication and learning activities between people with developmental disabilities. These results suggest the possibility of a role for technology-supported intervention and highlight the need for rigorous controlled research. RCT are especially significant for effectiveness assessment of interventions. Randomized controlled trials have been recognized as a powerful research design method as it minimizes selection bias and enhances causal interpretation (Sibbald & Roland, 1998). An RCT design can be used to understand if there are improvements with ASD communication intervention when using AI-assisted therapy versus traditional speech therapy. This is because many studies conclude there are benefits to technology use, but fewer studies compare technology assisted to standard therapy in a way that equates the length of the therapy and standardized outcome measures. Comparative research is even more essential in low-resource environments. The majority of technology assisted autism intervention studies have been carried out in high-income countries. They may not necessarily be applicable to Pakistan due to divergent

language, cultural, access to various type of therapies, parent education and digital literacy and institutional resources. Hence, local evidence is required to be explored in terms of the effectiveness of speech therapy with the aid of Artificial Intelligence on the following domains of expressive language, receptive language, social communication, engagement and adherence to therapy among children with ASD from Pakistan.

Literature Gap

The literature reviewed indicates that communication delays play a major role in ASD and are likely to impact on a child's social, educational, and adaptive functioning. Traditional speech therapy continues to be a significant evidence-based intervention, particularly given its ability to deliver direct human interaction, individualized feedback and structured clinical support. Conversely, AI-driven speech therapy provides fresh possibilities with adaptive feedback, gamification, home therapy sessions, and greater accessibility. But there is not enough comparative evidence, available at present, of Traditional Speech Therapy versus AI-Assisted Speech Therapy, especially in Pakistan. The majority of existing research focuses on either technology-based or traditional interventions, and there are fewer studies that have adopted a randomized controlled approach to compare technology-based and traditional interventions. So, for this purpose, the present study tried to examine the effectiveness of Traditional Speech Therapy (TST) and AI-Assisted Speech Therapy (AIAST) in relation to the communication outcome of ASD children in Pakistan.

Methodology

This study applied a randomized controlled trial (RCT) design to investigate the effectiveness of Traditional Speech Therapy (TST) vs AI-Assisted Speech Therapy (AIAST) for improving communication outcomes in children with Autism Spectrum Disorder (ASD). This intervention study was not prospectively registered as an investigator-initiated study. The study was carried out in certain special education schools, autism rehabilitation centers, and speech

therapy clinics in Pakistan. Children who were diagnosed with ASD were recruited, with 100 children being equally divided among the TST group ($n = 50$) and AIST group ($n = 50$) between the ages of 5 and 12. A sample size of 100 was deemed to be sufficient for a balanced comparison between the two intervention groups and for any meaningful differences in communication outcomes to become apparent. Children were included if they had a confirmed ASD diagnosis, mild to moderate communication difficulties, and were able to attend structured therapy sessions. Children were excluded if they had severe intellectual disability, a major neurological problem, an extensive prior exposure to AI speech therapy, or if they had significant hearing loss unrelated to ASD. Eligible participants were identified using purposive sampling; the two groups were then computer-generated randomly assigned. Speech and language therapy were delivered one-on-one with certified Speech-Language Pathologists to the TST group and supervised (with support provided by AI platforms) to the AIST group with Speech Blubs, Otsimo Speech Therapy, and Lingraphica TalkPath Therapy. The three groups

were given three sessions, each 45 minutes long, weekly for 12 weeks (36 sessions total). Attendance, session time, and therapy activities were recorded to ensure fidelity and reviewed weekly. The CCC-2, Vineland Communication Domain, ATEC Communication Subscale, and Therapist Observation Checklist had Cronbach's alpha values of .91, .88, .86, and .89, respectively, for communication outcomes. Qualitative data were collected by trained evaluators who were blind to group allocation at baseline and following the intervention. IBM SPSS Statistics Version 27 was used to analyze the data. Descriptive statistics, independent-samples t -tests, chi-square tests, paired-samples t -tests, Shapiro-Wilk tests, Levene's tests, ANCOVA, 95% confidence intervals, and Cohen's d effect sizes were used. A p -value less than .05 was considered statistically significant. Ethical approval was obtained from the appropriate institutional ethics committee, and informed written consent was obtained from parents/guardians; confidentiality and anonymity were maintained throughout the study, and no one was forced to participate.

Results

Table 1 Baseline Demographic and Clinical Characteristics of Participants

Variable	TST ($n = 50$)	AIST ($n = 50$)	Test Statistic	p
Continuous Variables				
Age (years), Mean $\pm$ SD	8.3 $\pm$ 1.8	8.5 $\pm$ 1.9	$t(98) = 0.53$	.60
Baseline ATEC Score, Mean $\pm$ SD	54.5 $\pm$ 8.4	53.9 $\pm$ 8.7	$t(98) = 0.35$	.73
Baseline CCC-2 Score, Mean $\pm$ SD	61.8 $\pm$ 6.9	62.3 $\pm$ 6.7	$t(98) = 0.37$	.71
Categorical Variables				
Gender (Male/Female), n	36 / 14	35 / 15	$\chi^2(1) = 0.05$	.82
ASD Severity (Mild/Moderate), n	27 / 23	28 / 22	$\chi^2(1) = 0.04$	.84

Variable	TST (n = 50)	AIST (n = 50)	Test Statistic	p
Previous Therapy (Yes/No), <i>n</i>	18 / 32	19 / 31	$\chi^2(1) = 0.05$	.82

Note. Values are presented as mean $\pm$ standard deviation (SD) or frequency (*n*). TST = Traditional Speech Therapy; AIST = AI-Assisted Speech Therapy; CCC-2 = Children's Communication Checklist–Second Edition; ATEC = Autism Treatment Evaluation Checklist.

Table 1 shows the demographic and clinical baseline characteristics of the participants in the Traditional Speech Therapy (TST) and AI-Assisted Speech Therapy (AIST) groups before the intervention. Comparisons of continuous variables were made using independent-samples t-tests, and categorical variables were compared using chi-square (χ^2) tests. The results showed there were no significant differences between the two groups on the following variables: age ($p >$

.05), baseline communication ability (CCC-2) ($p > .05$), baseline autism symptom severity (ATEC) ($p > .05$), gender distribution ($p > .05$), ASD severity ($p > .05$), or past therapy exposure ($p > .05$). The results here show that the groups were randomized into similar ones at baseline, which decreases the risk for pre-existing demographic or clinical variables to account for differences in the post-intervention results.

Table 2 Descriptive Statistics for Pre- and Post-Intervention Communication Outcomes

Outcome Measure	TST Pre	TST Post	Change	AIST Pre	AIST Post	Change
CCC-2 Total Score	61.8 $\pm$ 6.9	72.6 $\pm$ 6.4	+10.8	62.3 $\pm$ 6.7	81.2 $\pm$ 5.3	+18.9
Vineland Communication	59.2 $\pm$ 7.8	69.1 $\pm$ 7.0	+9.9	59.6 $\pm$ 7.4	78.1 $\pm$ 6.1	+18.5
ATEC Communication	14.2 $\pm$ 3.1	9.5 $\pm$ 2.6	−4.7	14.0 $\pm$ 3.2	6.8 $\pm$ 2.1	−7.2
Eye Contact	2.3 $\pm$ 0.7	3.2 $\pm$ 0.6	+0.9	2.2 $\pm$ 0.7	3.9 $\pm$ 0.5	+1.7
Verbal Initiation	2.2 $\pm$ 0.6	3.1 $\pm$ 0.6	+0.9	2.1 $\pm$ 0.6	3.8 $\pm$ 0.5	+1.7
Turn-Taking	2.4 $\pm$ 0.5	3.3 $\pm$ 0.5	+0.9	2.3 $\pm$ 0.5	3.9 $\pm$ 0.4	+1.6

Note. Higher scores indicate better communication performance for the CCC-2, Vineland Communication Domain, and therapist observation measures. Lower scores on the ATEC Communication Subscale indicate greater improvement in communication-related symptoms.

Table 2 shows that both the Traditional Speech Therapy (TST) and AI-Assisted Speech Therapy (AIST) groups improved after the 12-week intervention. The improvement was always higher in the AIST group, though. The AIST group showed larger gains in CCC-2 (+18.9 vs. +10.8), Vineland Communication (+18.5 vs. +9.9), eye contact (+1.7 vs. +0.9), verbal initiation (+1.7 vs. +0.9), and turn-taking (+1.6 vs. +0.9). Furthermore, AIST group scores

decreased by more than the TST group scores (ATEC Communication: −7.2 vs. TST: −4.7), suggesting a more significant improvement in Communication symptoms. The descriptive results indicated that overall, this use of AI-Assisted Speech Therapy yielded greater gains for standardized communication measures and greater gains for the therapist's observation of the child's social communication behaviors than did Traditional Speech Therapy.

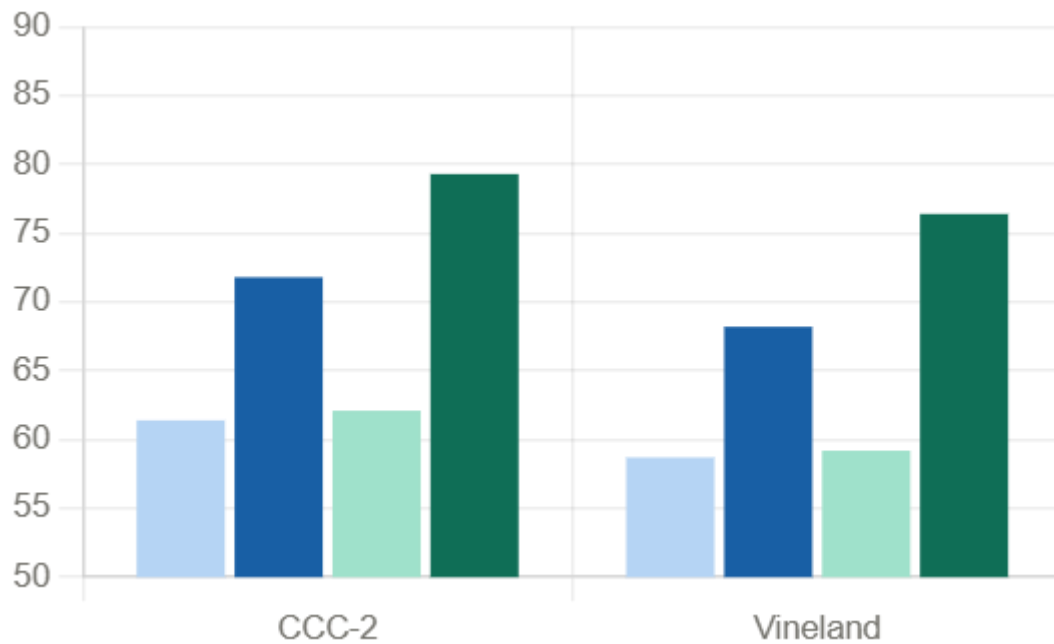


Figure 2. Pre- and Post-Intervention Scores on the CCC-2 and Vineland Communication Domain

Figure 2 illustrates the mean pre- and post-intervention scores for the CCC-2 and Vineland Communication Domain in both intervention groups. Both TST and AI-Assisted Speech Therapy (AIST) groups showed improvements after 12 weeks of the intervention. The results indicated that, however, the gains of the AIST group were significantly larger on both the standardized measures of communication, in

terms of mean score increases after treatment, than those of the non-AIST group. The findings from this descriptive study were similar to those of the inferential analysis and showed that the improvements in communication outcomes were greater for those who received speech therapy through AI than for those who received speech therapy alone.

Table 3. Assumption Testing for Normality and Homogeneity of Variance

Outcome Measure	Group	Shapiro–Wilk <i>W</i>	<i>p</i>	Levene's <i>F</i>	<i>p</i>
CCC-2 Total Score	TST	.97	.21	1.42	.24
	AIST	.96	.18	—	—
Vineland Communication	TST	.98	.31	1.18	.28
	AIST	.97	.25	—	—
ATEC Communication	TST	.96	.16	1.35	.25
	AIST	.97	.22	—	—
Eye Contact	TST	.95	.09	1.61	.21
	AIST	.96	.13	—	—

Outcome Measure	Group	Shapiro–Wilk <i>W</i>	<i>p</i>	Levene's <i>F</i>	<i>p</i>
Verbal Initiation	TST	.96	.14	1.28	.26
	AIST	.97	.20	—	—
Turn-Taking	TST	.95	.11	1.73	.19
	AIST	.96	.15	—	—

Note. TST = Traditional Speech Therapy; AIST = AI-Assisted Speech Therapy. Non-significant Shapiro–Wilk ($p > .05$) and Levene's tests ($p > .05$) indicate that the assumptions of normality and homogeneity of variance were satisfied.

Before conducting inferential analyses, the assumptions of normality and homogeneity of variance were examined. The normality test was conducted with Shapiro–Wilk test and the Levene's test was used for the homogeneity of variance test. All Shapiro–Wilk tests were non-significant ($p > .05$), suggesting that the outcome variables were approximately normally distributed (Table 3). Likewise, all outcome measures for all Levene tests were not significant ($p > .05$), thus ensuring equality of variances between the TST and AIST groups. These results suggested that the assumptions needed to

perform parametric statistical analysis procedures were met. To assess the effects of the interventions, therefore, paired-samples *t*-tests, independent-samples *t*-tests, and ANCOVA were used.

Within-Group Comparisons

Paired-samples *t*-tests were conducted to examine whether participants in each intervention group showed significant improvement from pre-test to post-test. The results are presented in Table 4.

Table 4: Within-Group Comparisons Using Paired-Samples *t*-Tests

Outcome Measure	Group	Mean Difference	SD Difference	95% CI	<i>t</i> df	<i>p</i>
CCC-2 Total Score	TST	10.8	4.2	[9.61, 11.99]	18.18 49	< .001
	AIST	18.9	4.0	[17.76, 20.04]	33.41 49	< .001
Vineland Communication	TST	9.9	4.5	[8.62, 11.18]	15.56 49	< .001
	AIST	18.5	4.1	[17.33, 19.67]	31.91 49	< .001
ATEC Communication	TST	−4.7	1.9	[−5.24, −4.16]	−17.49 49	< .001
	AIST	−7.2	2.0	[−7.77, −6.63]	−25.46 49	< .001

Note. CI = confidence interval; TST = Traditional Speech Therapy; AIST = AI-Assisted Speech Therapy. Lower scores on the ATEC Communication Subscale indicate improvement.

Table 4 indicates that there were statistically significant differences between pre-test and post-test for all standardized measures of communication in both intervention groups ($p < .001$). The size of improvement, however, was always higher in the AIST group compared with

the TST group. The AIST group demonstrated significantly higher increases on the CCC-2 (18.9 vs. 10.8) and Vineland Communication Domain (18.5 vs. 9.9), which reflects greater gains in communication performance. Likewise, ATEC Communication scores were also lower in the

AIST group (-7.2) than those of the TST group (-4.7), indicating that there was more reduction within the AIST group in the communication-related symptoms. The results show that both treatments led to improvements, with AI-Assisted Speech Therapy resulting in greater improvements within-group compared to Traditional Speech Therapy.

Between-Group Comparisons at Post-Intervention

Independent-samples *t*-tests were conducted to compare post-intervention outcomes between the TST and AIST groups. The results are presented in Table 5.

Table 5: Between-Group Comparisons at Post-Intervention

Outcome Measure	TST Post M $\pm$ SD	AIST Post M $\pm$ SD	MD	95% CI	<i>t</i>	df	<i>p</i>
CCC-2 Total Score	72.6 $\pm$ 6.4	81.2 $\pm$ 5.3	8.6	[6.27, 10.93]	7.32	98	< .001
Vineland Communication	69.1 $\pm$ 7.0	78.1 $\pm$ 6.1	9.0	[6.39, 11.61]	6.85	98	< .001
ATEC Communication	9.5 $\pm$ 2.6	6.8 $\pm$ 2.1	-2.7	[-3.64, -1.76]	-5.71	98	< .001
Eye Contact	3.2 $\pm$ 0.6	3.9 $\pm$ 0.5	0.7	[0.48, 0.92]	6.34	98	< .001
Verbal Initiation	3.1 $\pm$ 0.6	3.8 $\pm$ 0.5	0.7	[0.48, 0.92]	6.34	98	< .001
Turn-Taking	3.3 $\pm$ 0.5	3.9 $\pm$ 0.4	0.6	[0.42, 0.78]	6.62	98	< .001

Note. CI = confidence interval; TST = Traditional Speech Therapy; AIST = AI-Assisted Speech Therapy. Higher CCC-2, Vineland, and therapist observation scores indicate better communication performance. Lower ATEC Communication scores indicate greater symptom reduction.

Table 5 indicates that the AIST group had significantly higher scores at post-test than the TST group in all communication measures ($p < .001$). The AIST group had higher scores for the CCC-2 and Vineland Communication Domain, suggesting higher levels of improvement in overall communication, expressive language, receptive communication, and social communication. The AIST group also had significantly lower ATEC Communication scores, indicating greater reduction in communication related symptoms. Further, therapist observation ratings of eye contact,

verbal initiation, and taking turns were significantly higher for the AIST group. The results suggest that AI-Assisted Speech Therapy (AAS) was more effective than Traditional Speech Therapy (TS) in enhancing standardized communication and functional social communication behaviors. These findings support Hypothesis 1, confirming that children receiving AI-Assisted Speech Therapy demonstrated significantly greater improvements in communication outcomes than children receiving Traditional Speech Therapy.

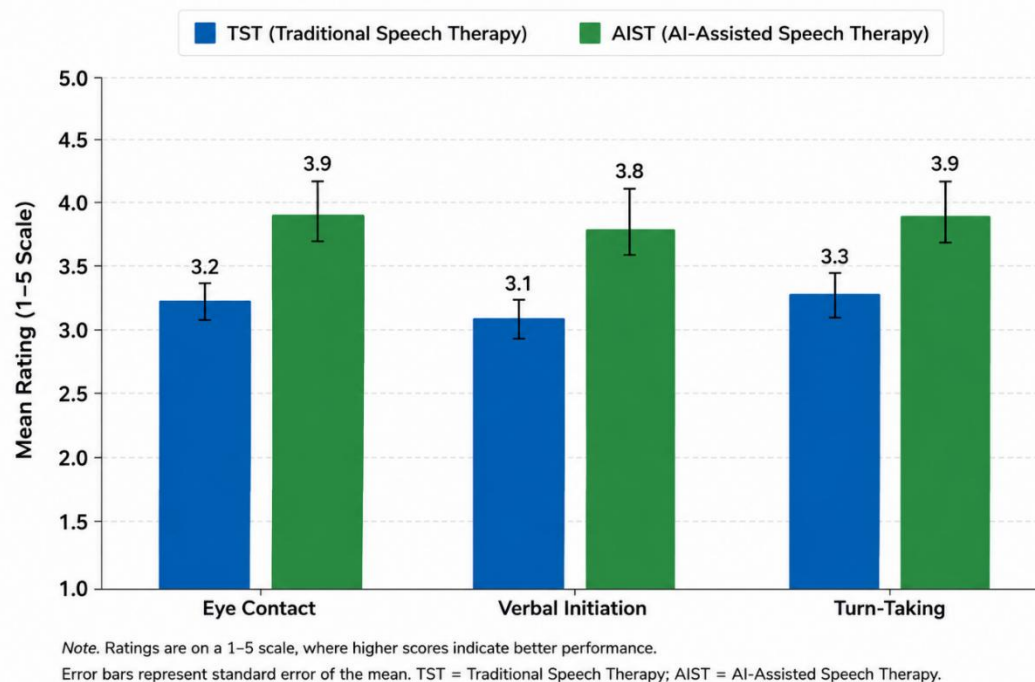


Figure 3. Therapist observation ratings (1-5 scale)

Figure 3 shows the therapist-rated communication behaviors after 12 weeks of intervention. The mean scores for eye contact, verbal initiation, and turn-taking were higher in the AI-Assisted Speech Therapy (AIST) group compared to the Traditional Speech Therapy (TST) group. The findings are consistent with the statistical results shown in Table 5 and suggest that functional social communication behavior was improved more when the teachers used AI-supported speech therapy.

ANCOVA Analysis

To further evaluate the effectiveness of the interventions while controlling for baseline differences, an Analysis of Covariance (ANCOVA) was performed. Each outcome measure score at post intervention was entered as the dependent variable, treatment group (TST vs. AIST) specified as the fixed factor, and the baseline score of each outcome measure was entered as the covariate. The assumptions of linearity, homogeneity of regression slopes and homogeneity of variance were checked before the analysis, and the results were satisfactory. Table 6 shows the results.

Table 6: ANCOVA Results Controlling for Baseline Scores

Outcome Measure	Covariate	Adjusted Mean (TST)	Adjusted Mean (AIST)	$F(1, 97)$	p	Partial η^2
CCC-2 Total Score	Pre CCC-2	72.7	81.1	52.84	< .001	.353
Vineland Communication	Pre Vineland	69.2	78.0	47.16	< .001	.327
ATEC Communication	Pre ATEC	9.4	6.9	31.82	< .001	.247

Note. Adjusted means represent post-intervention scores after controlling for baseline performance. Partial η^2 values of .01, .06, and .14 indicate small, medium, and large effect sizes, respectively.

Table 6 presents the ANCOVA results after controlling for baseline communication

performance. Pre-intervention scores were accounted for, and significant group differences

were found for all of the outcome measures ($p < .001$), with the AIST group still performing better than the TST group. The AIST group had higher adjusted mean scores in the CCC-2 and Vineland Communication Domain, indicating greater gains in overall communication skills. The AIST group, however, had lower adjusted ATEC Communication scores, which suggested that this group experienced greater improvement in communication-related symptoms. Partial eta-squared values ranged from .247 to .353 which

to determine the practical significance of the intervention effects. The results are presented in Table 7.

Table 7: Cohen's d Effect Sizes for Communication Outcomes

Outcome Measure	TST Within-Group d	AIST Within-Group d	Between-Group d
CCC-2 Total Score	1.62	3.10	1.46
Vineland Communication	1.34	2.72	1.37
ATEC Communication	1.64	2.66	1.14
Eye Contact	1.38	2.78	1.27
Verbal Initiation	1.50	3.09	1.27
Turn-Taking	1.80	3.56	1.33

Note. Cohen's d values of 0.20, 0.50, and 0.80 indicate small, medium, and large effects, respectively. TST = Traditional Speech Therapy; AIST = AI-Assisted Speech Therapy.

Table 7 presents the practical magnitude of intervention effects using Cohen's d . For both interventions, the within-group effects were large across all communication outcomes, suggesting that there was a meaningful intervention effect within both groups. This was not the case for the AIST group, though, which showed consistently larger effect sizes within groups than the TST group, indicating greater therapeutic benefits with AI intervention. The effect sizes between groups ranged from 1.14 to 1.46, which were all greater than the typically accepted criterion of a large effect size. These results suggest that the effects of AI-Assisted Speech Therapy were not just statistically significant but also clinically significant compared to Traditional Speech Therapy.

indicate large intervention effects. The results align with Hypothesis 1 and validate the significance of the communication effects in the AI-Assisted Speech Therapy condition compared to Traditional Speech Therapy, even when controlling for differences in baseline communication skills.

Effect Size Analysis

Cohen's d was calculated

CONSORT Participant Flow

The flow of participants throughout the randomized controlled trial is shown in Figure 4. A total of 118 children were assessed for eligibility. 18 participants were excluded as they did not meet the inclusion criteria or refused to participate. The remaining 100 participants who qualified for the study were randomly divided into the Traditional Speech Therapy (TST) group ($n = 50$) and AI-Assisted Speech Therapy (AIST) group ($n = 50$). There were no losses to follow-up or exclusions from analysis during the 12-week intervention. As a result, we included data from all individuals who were recruited on a randomized basis.

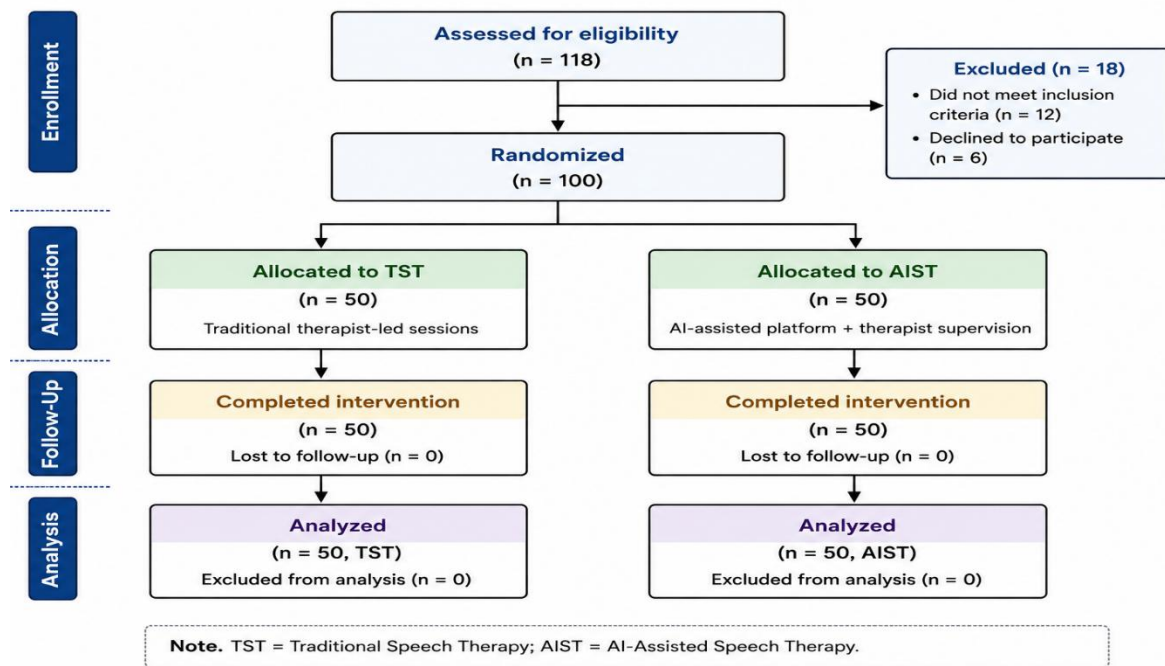


Figure 4 – CONSORT Participant Flow Diagram

Figure 4 illustrates the flow of participants through each stage of the randomized controlled trial in accordance with the CONSORT reporting guidelines. All eligible participants were successfully randomized into the two intervention groups, and no participants were lost to follow-up or excluded from the final analysis. The absence of attrition ensured complete outcome data for all randomized participants, thereby strengthening the internal validity of the trial and minimizing the potential risk of attrition bias.

Discussion

The present study aimed to compare the effectiveness of Traditional Speech Therapy (TST) and AI-Assisted Speech Therapy (AIST) in enhancing communication outcomes of children with Autism Spectrum Disorder (ASD) in the context of Pakistan. The results confirmed the research hypothesis, revealing that children using the AI-Assisted Speech Therapy had significantly higher gains compared to those using the Traditional Speech Therapy. This superiority was seen on standardized communication measures, communication behaviors observed by therapists, ANCOVA adjusted outcomes, and on estimates of effect size. The findings show that AIST achieved greater improvements in overall

communication, receptive language, expressive language, social communication, eye contact, verbal initiation and turn taking skills. The findings are similar to the quantitative results of the present study, in which the AIST group showed better performance than the TST group on CCC-2, Vineland, ATEC, and therapist-observed outcomes.

This improvement could be attributed to the structured, adaptive, and interactive nature of platforms for speech therapy supported by AI. While traditional therapy relies primarily on therapist-directed teaching and in-person feedback, AI-powered tools offer repeated practice, visual cues, instant feedback, and gamified learning activities. These can help to capture children's interest and encourage them to engage in communication activities. The result is in line with Grynszpan et al. (2014) who found that technology-based interventions may enhance learning and social communication for people with ASD. Likewise, Ploog et al. (2013) pointed out that, based on the need for repetitive and predictable structure and visual clarity, computer-assisted interventions are helpful for children with ASD. Thus, the increase in communication in the AIST group may be

attributable to the joint impact of therapists' supervision and technology-assisted practice.

The results are also consistent with earlier studies that demonstrated that the technology-based communication intervention can improve functional communication in children with developmental disabilities. Binger and Light (2007) concluded that modeling of aided communication facilitated the production of multi-symbol messages for children who use augmentative and alternative communication. Miranda (2003) also noted that technology-supported communication systems are effective in improving functional communication if they are used within natural contexts. In the present study, children in the AIST group showed stronger improvements not only in standardized communication scores but also in therapist-observed behaviors such as eye contact, verbal initiation, and turn-taking. This indicates that AI-based therapy could be a factor in formal language acquisition and in real-life social communication abilities.

The Vygotsky Zone of Proximal Development (ZPD) can also be applied to the results of the improvement that occurred in the AIST group. Vygotsky (1978) believed that children learn best when activities are offered that are just beyond their current ability level. This support is traditionally offered by speech therapy via direct instruction, modelling, prompts and feedback. AI-enhanced platforms can enhance this process by providing adaptive scaffolding, immediate feedback and increasing task complexity. Thus, AIST can assist children to stay in the desired 'zone of proximal development' (ZPD) in which tasks are neither too easy nor too hard. Kasari et al. (2008) highlighted the significance of structured support, joint attention and social engagement in enhancing communication outcomes for children with ASD.

In addition, the findings are consistent with the Technology Acceptance Model (TAM) developed by Davis (1989) that indicates that users will be more likely to use technology if they believe it is useful and easy to use. TAM was created to describe the use of technology by

adults, but it applies to the present study because artificial intelligence (AI) enabled technology platforms usually have visual feedback, rewards, games, and interactive learning activities. These features can improve children's interest and motivation in therapy. Parsons and Cobb (2011) mentioned that the technology-based learning environment can offer a safe and controlled environment for children with ASD to practise social and communication skills. Likewise, Bölte et al. (2010) suggested that technology can be beneficial for interventions for individuals with autism when it is well-designed and clinically well-supervised. The current results build on this evidence since they demonstrate that AI-supported therapy, under the guidance of a therapist, can yield greater communication results than traditional therapy alone.

The marked decrease in ATEC Communication scores in the AIST group is also noteworthy as lower ATEC scores are associated with fewer communication-related problems. This discovery indicates that AI-supported therapy can not just enhance the performance of communication but in addition cut down on noticeable communication-related symptoms linked to ASD. The results are similar to the findings by Ramdoss et. al. (2011) in their review of computer based interventions for children with ASD and how they may help enhance communication and learning outcomes. In the same way, Kagohara et al. (2013) found that communication and learning can be facilitated through the use of tablet computers and handheld technologies among people with developmental disabilities. The present study contributes to this evidence through a randomized controlled design and by directly comparing AI-assisted therapy with traditional speech therapy.

The findings of the present study further support the clinical significance of the effects seen with large effect sizes. Both groups showed gains following the 12 week intervention however the gains were relatively larger for the AIST group in both within and between group effect sizes. This means that the difference between the two intervention approaches was not only statistically

significant, but practically significant as well. This is crucial for clinical decision making as statistical significance does not necessarily imply clinically relevant therapeutic change. These large Cohen's d scores indicate that the use of AI-assisted therapy could have clinically significant impacts for children with ASD, especially when combined with therapist-led therapy.

The results of ANCOVA further contribute to the support of the effectiveness of AIST. Baseline communication performance did not significantly impact the outcomes of the AIST group, which remained significantly better than those of the control group following the intervention. This means that the ability to communicate better did not exist already between the groups of AIST. The results, however, show that the intervention was responsible for the greater improvements that were seen in the AIST group. This enhances the internal validity of the study and justifies the conclusion that using AI for speech therapy can be a valuable method of intervention when working with children with ASD.

The results of this study have significant implications for Pakistan where access to specialized speech-language services is limited. While traditional speech therapy is effective, there are many challenges in accessing traditional services for families that include cost, distance, few-trained speech therapists and limited specialized autism services. Rahbar et al. (2011) emphasized the importance of raising the awareness of autism and the development of services in Pakistan. In this context, AI-enabled speech therapy could serve as a valuable complement to traditional therapy, offering more practice time out of the clinic and aiding in the continuity of care between sessions. The results are not intended to imply that AI tools can be used to replace qualified Speech-Language Pathologists, however. Instead, the findings suggest that the effectiveness of AI-assisted therapy lies in its combination with professional guidance, personalized treatment plans, and therapist oversight.

Structured digital support, gamification, feedback and the inclusion of technology in a comprehensive speech therapy model have been previously associated with better speech outcomes. As with any other study, the present study indicates that artificial intelligence facilitated therapy may be more effective when combined with traditional therapy approach, as opposed to standing alone. This blend can be even more useful in inclusive and resource-limited settings.

There are a number of weaknesses, however, that need to be recognized. First, the study was conducted with children between 5 and 12 years of age with mild to moderate communication difficulties, and the results may not be applicable to children with severe ASD, severe intellectual disabilities, and children with complex neurological issues. Second, the study followed up for 12 weeks after the intervention, but did not carry out long term follow-up. Future studies should investigate if communication improvements will persist following the end of the intervention. Third, while standardized tools and therapist observation measures were used, results of parent-reported measures and classroom-based measures of communication could add additional information regarding actual communication function in the real world. Fourth, the level of language accuracy, cultural relevance and suitability of AI assisted platforms can differ among children in Pakistan, as the country is linguistically diverse. This study should be extended to explore the performance of the AI tools in other regional languages such as Urdu, Punjabi, Pashto, Sindhi, etc.

The results showed that overall, children with ASD who received Traditional Speech Therapy (TS) did not achieve the same improvements in communication outcomes as those who received AI-Assisted Speech Therapy (AS). The findings suggest that using AI-supported platforms as an additional and supervised intervention in SALT is feasible. AI-assisted therapy could further enhance children's functional communication abilities and increase the intensity of therapy sessions in Pakistan, where access to specialized therapy is limited. However, professional

supervision, culturally appropriate adaptation, data privacy protections, parent training and careful monitoring of screen-based activities will be needed to ensure the successful implementation. AI-enabled speech therapy is therefore seen as a promising, effective tool to complement, not replace, human clinical practices in speech therapy.

Conclusion

This randomized controlled trial (RCT) findings proved that communication results of children with Autism Spectrum Disorder (ASD) were positively influenced by both Traditional Speech Therapy (TST) and AI-Assisted Speech Therapy (AIST). Participants receiving AI-Assisted Speech Therapy, however, had significantly more gains on standardized communication measures, therapist observed communication behaviors, and overall communication performance compared to those receiving Traditional Speech Therapy. Large effect sizes demonstrated the superiority of AIST, which also remained significant when controlling for baseline communication abilities, suggesting both statistical and clinical significance.

The results indicate that using AI in speech therapy is an effective and evidence-based method for improving children with ASD's functional communication, social communication, receptive language, and expressive language skills. The adaptability of AI platforms, such as the ability to provide feedback in real-time, tailor learning experiences per user, repeat work, and embed activities in the learning process, can help increase communication outcomes when combined with the therapist provided intervention.

AI speech therapy holds great promise for augmenting traditional clinical practice in a context like Pakistan where the resources of qualified Speech-Language Pathologists and specialized autism services are scarce. AI tools are not meant to substitute for professional speech-language pathologists, but rather to supplement therapeutic care to enhance therapy intensity,

expand therapy opportunities outside the clinic, and provide evidence-based intervention. However, to implement successfully, the process needs to be professionally supervised, AI tools need to be culturally and linguistically sensitive, training needs to be adequate, and considerations need to be taken with regards to ethical issues, such as data privacy and responsible use of technology.

The study did show promising results for the effectiveness of the AI-assisted intervention, but it only included children with mild to moderate communication difficulties and was only tested over a 12-week period. Future studies should involve larger and more diverse samples to assess long-term outcomes and generalizability of AI-enabled speech therapy to varying age groups, ASD severity, and linguistic and cultural settings, as well as multicenter randomized controlled trials.

The results show that AI-Assisted Speech Therapy is a promising and effective approach to enhancing communication skills for children with Autism Spectrum Disorder and could complement Traditional Speech Therapy. It could be integrated into speech-language rehabilitation services to improve the quality, availability and effectiveness of rehabilitation services, especially in low-resource health and education environments like Pakistan.

AI assisted speech therapy could be regarded as supplement to children with ASD's speech-language rehabilitation services, according to the results of this study. Educational institutions, rehabilitation centers, and healthcare providers should encourage the adoption of such AI-driven speech therapy platforms in clinical practice. Furthermore, policymakers should encourage culturally and linguistically responsive AI use, and future studies should assess long-term outcomes of AI tools in different populations and clinical contexts

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