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COMPARING TRADITIONAL AND AI-ASSISTED INTERVENTIONS FOR LANGUAGE RECOVERY IN ADULTS WITH APHASIA

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ABSTRACT

Background: *Aphasia is an acquired language disorder that significantly impairs communication and quality of life among stroke survivors. In Pakistan, the critical shortage of registered speech-language therapists relative to the population creates an urgent need for scalable rehabilitation alternatives.*

Objectives: This study compared the effectiveness of traditional speech-language therapy and AI-assisted interventions in improving language recovery among adults with aphasia in Pakistan.

Methods: *A quantitative quasi-experimental pre-test/post-test design was employed. Forty adults with mild-to-moderate aphasia were recruited from tertiary care hospitals in Lahore, Rawalpindi and Islamabad, Pakistan, and assigned to either a traditional therapy group (n = 20) or an AI-assisted therapy group (n = 20). Both groups received three sessions per week for eight to ten weeks. Language recovery was assessed across six domains using an Aphasia Language Recovery Assessment Scale. Data were analysed using paired and independent sample t-tests, ANCOVA (controlling for baseline scores), Mann-Whitney U test, Pearson correlation, and Cohen's d effect size.*

Results: *Both groups demonstrated statistically significant improvements from pre-test to post-test. However, the AI-assisted group achieved significantly higher post-test scores (M = 78.60, SD = 6.85) compared with the traditional group (M = 68.40, SD = 7.21), yielding a mean difference of 10.20 points, $t(38) = -4.58$, $p < .001$, 95% CI [−14.76, −5.64]. Cohen's d values ranged from 0.94 to 1.45, all indicating large effects. ANCOVA confirmed the group difference after controlling for baseline scores, $F(1, 37) = 19.61$, $p < .001$, partial $\eta^2 = .344$. Pearson correlation revealed a moderate negative association between diagnosis duration and recovery scores ($r = -0.48$, $p = .002$).*

Conclusion: *AI-assisted intervention produced superior language recovery outcomes across all domains compared with traditional therapy. Given Pakistan's severe speech-language therapy workforce shortage, AI-assisted rehabilitation represents a scalable, cost-effective, and linguistically adaptable solution for aphasia rehabilitation. Early referral and integration of AI tools into national rehabilitation policy are strongly recommended.*

Keywords: *aphasia rehabilitation, AI-assisted therapy, language recovery, Pakistan, neuroplasticity, quasi-experimental design, speech-language pathology*

INTRODUCTION

Aphasia and Its Prevalence

Aphasia is a neurogenic language disorder occurring after the onset of an acquired brain injury and in most cases is due to damage to the brain's language-dominant areas, primarily due to stroke, traumatic brain injury, brain tumor and other neurological disorders. The disorder involves an individual's understanding, production, reading, and writing of language, with a relatively intact general intelligence. Aphasia can occur in various forms such as Broca's, Wernicke's, global, anomic and conduction aphasia, with each having unique language impairment patterns (Dickey et al., 2010).

Stroke is still the most common cause of aphasia globally. Studies show that about one-third of all stroke patients will have some level of aphasia during the acute phase of recovery. Some spontaneous recovery can happen, but many people do have ongoing communication problems after the initial neurological event (Flowers et al., 2016). With the aging of the population worldwide and the growing prevalence of stroke, there will be more people living with aphasia, and more need for effective rehabilitation services.

The challenge of aphasia goes beyond the clinical issue and is a public health problem. Chronic communication difficulties may impact work, social roles, relationships, and mental health. Hence, enhancing rehabilitation of persons with aphasia is a major goal in speech-language pathology and neurorehabilitation (Engelter et al., 2006).

Impact on Communication and Quality of Life

Communication is essential for social inclusion, personal autonomy and human interaction. Aphasia interferes with these functions because it affects a person's ability to communicate verbally, to understand speech, to converse and to perform activities of daily living. People with aphasia may struggle in their interactions with family, health care providers, employers, and community (Hilari, 2011).

Aphasia affects more than the language. Communication challenges often lead people to feel frustrated, socially isolated, anxious and depressed. Limited access to social and recreational activities often leads to low self-esteem and a lower life satisfaction. These psychosocial impacts can have a detrimental impact on the patient and those who care for them (Cruice et al., 2006).

The measurement of quality of life has been an important outcome in aphasia rehabilitation in recent years. In addition to better language skills, the contemporary approaches to rehabilitation focus on better functional communication, social involvement and emotional health. Intervention should thus involve the overall consequences of aphasia for everyday functioning and help people reengage in society as a meaningful participant (Ross & Wertz, 2003).

Traditional Speech-Language Therapy

Traditional speech-language therapy has long been considered the cornerstone of aphasia rehabilitation. These interventions provide structured therapeutic activities that are designed to enhance language functioning in the areas of naming, comprehension, repetition, reading, writing and conversational skills. Based on the type and severity of aphasia and individual communication needs, treatment is generally tailored to the patient (Brady et al., 2016).

Intensive and sustained speech-language therapy has repeatedly been shown to help facilitate language recovery, by encouraging neuroplasticity and functional reorganization in the brain. Semantic feature analysis, constraint induced language therapy, melodic intonation therapy and script training have proven to help with communication skills in persons with aphasia (Cherney et al., 2008).

Although traditional Speech-Language Therapy is effective, there are a number of challenges. Sometimes, speech-language pathologists may not be available, financial resources are limited, transportation can be an issue, and therapy intensity is not adequate. In addition, many people need a high amount of practice outside of the clinic to obtain the best recovery results.

These restrictions have spurred researchers and clinicians to develop technology-based interventions as supplements to conventional interventions (Simmons-Mackie et al., 2017).

AI in Speech-Language Therapy

In recent years, with the advent of artificial intelligence (AI), more and more fields of healthcare have been revolutionized, such as speech-language pathology. AI technologies can be used to analyse speech and language patterns, deliver feedback automatically, tailor treatment, track patient progress and adjust treatment difficulty level based on individual performance. These capabilities have opened up new possibilities for language rehabilitation of persons with aphasia (Topaz et al., 2019).

AI speech therapy apps can provide intensive at-home training, enabling patients to perform therapeutic exercises in non-clinical environments.This can help to provide intensive at-home training, giving the person the opportunity to engage in therapeutic exercises outside of the clinical setting with the help of an AI-assisted speech therapy app. Advanced algorithms of machine learning can detect patients' strengths and weaknesses and create personalized activities and give instant feedback. These can help to make treatment more intense, more patient-focused and more efficient in rehabilitation (Fraser et al., 2022).

AI-powered interventions can also help alleviate the shortage of rehabilitation services and time and cost constraints. This has sparked considerable interest in the integration of AI into speech-language therapy by researchers looking for novel approaches to rehabilitation for people with aphasia. Yet, there is a lack of evidence on the comparative effectiveness of interventions using AI, which needs to be explored further (Lavoie et al., 2023).

Research Gap

While technology-based rehabilitation (TbR) has grown in use in speech-language pathology over the years, the number of studies directly comparing the effectiveness of AI-assisted interventions to traditional therapist-led interventions for adults with aphasia has been relatively small. The majority of previous studies that examined the usability, feasibility and patient satisfaction outcomes did not assess comparative treatment outcomes across multiple language domains (Kurland et al., 2018).

Moreover, the generalizability of the findings from previous studies was limited due to the small sample size, different intervention protocols and different outcome measures used. The evidence is still not clear if AI-assisted interventions can lead to language recovery that is equal to or better than traditional speech-language therapy. This empirical evidence is highly absent in the existing literature.

In conclusion, additional studies are required to explore the efficacy of the AI-based intervention for aphasia and to understand its implications for current speech-language therapy practice. Filling this gap could help clinicians with evidence-based recommendations for incorporating AI into rehabilitation programs.

Study Objectives

To compare the effectiveness of traditional speech-language therapy and AI-assisted interventions for language recovery in adults with aphasia.

To evaluate improvements in expressive language skills following traditional and AI-assisted interventions.

To assess changes in receptive language abilities among adults with aphasia after intervention.

To determine the effectiveness of AI-assisted therapy in enhancing functional communication outcomes.

Hypotheses

H1: There will be a statistically significant difference between traditional speech-language therapy and AI-assisted interventions in improving language recovery among adults with aphasia.

H2: Adults receiving AI-assisted interventions will demonstrate significantly greater improvements in expressive language skills than those receiving traditional speech-language therapy.

H3: Adults receiving AI-assisted interventions will demonstrate significantly greater improvements

in receptive language skills than those receiving traditional speech-language therapy.
H0: There will be no statistically significant difference between traditional speech-language therapy and AI-assisted interventions in language recovery outcomes among adults with aphasia.

Literature Review

Aphasia Rehabilitation

One of the most important areas of speech-language therapy is the rehabilitation of aphasia, as the condition impacts how a person comprehends, communicates, reads and writes language. Rehabilitation is designed to improve language skills, functional communication and participation in everyday life. Speech-language therapy is regarded as the primary clinical intervention for persons with aphasia particularly following stroke. Structured therapy has been demonstrated to enhance functional communication, expressive language, reading and writing abilities in individuals with aphasia (Brady et al., 2016).
Treatment for aphasia is typically designed based on the type, severity and communication needs of the person. Therapy can be targeted to word retrieval and sentence production, or it can be targeted to comprehension, repetition, reading, writing or social communication for some patients. Therefore, rehabilitation should be tailored and focused on each individual's needs and progress, with goals set and continually monitored (Simmons-Mackie et al., 2017).

Neuroplasticity and Language Recovery

Neuroplasticity has strong associations with language recovery following aphasia. The brain's ability to change its structure and functions in response to injury is called neuroplasticity. After stroke or brain damage, there is a possibility that undamaged areas of the brain can support recovery by establishing new connections and compensating for the damaged networks of language (Puderbaugh & Emmady, 2023).
Speech-language therapy helps promote neuroplasticity by engaging in repeated language practice, meaningful language practice, and task-specific language practice. The intensive stimulation of language can support the reorganization of language functions in the brain and enhance communication results. Typically, some factors affect recovery, such as lesion location, aphasia severity, and duration since stroke onset, age, motivation, and therapy intensity (Saur et al., 2006).

Traditional Interventions

Traditional aphasia interventions typically involve structured activities for naming, auditory comprehension, repetition, reading, writing, and conversational practice, and are usually therapist-led. These are some of the commonly used interventions such as semantic feature analysis, melodic intonation therapy, constraint induced language therapy, script training and functional communication therapy. These are intended not only to enhance the accuracy of language but also to enhance the ability to communicate in the real world (Cherney et al., 2008).
The traditional approach is very useful as it provides direct patient-speech-language therapist interaction. The therapist can note errors, cue, modify activities and address emotional and social communication needs. However, traditional therapy could be constrained due to a lack of therapists, cost, transportation issues, and limited therapy time. These difficulties limit opportunities for intensive practice, necessary for long-term recovery (Rose et al., 2013).

AI-Assisted Interventions

AI has opened up new avenues in speech-language therapy for assessment, treatment planning, feedback, and progress monitoring. Speech and language responses can be analyzed by AI tools, which can help identify patterns of errors, adapt the difficulty level of tasks, and offer individual therapy exercises. These functions can facilitate independent practice and enhance therapy intensity outside of the therapy setting (Azevedo et al., 2023).
AI-supported interventions could be particularly beneficial for adults with aphasia as they can offer repetitive practice at home. Patients can use digital platforms and apps with AI support to engage in the practice of naming,

comprehension, repetition, reading, and writing tasks with immediate feedback. They can also help speech-language therapists monitor patients' progress and pinpoint areas that need more clinical attention (Zhong et al., 2024).

Previous Comparative Studies

The use of computer-based and digital therapy as a supplement to speech-language therapy has been found to be useful in the rehabilitation of individuals with aphasia in previous studies. Nonetheless, there is evidence demonstrating positive outcomes for language practice and patient engagement using programs in tablet and at home. However, a lot of studies have been conducted on feasibility and usability instead of directly comparing the traditional approach with the approach using AI (Kurland et al., 2018).

Finally, massive trials of self-managed computer-assisted aphasia therapy have demonstrated that such a therapy is effective at enhancing word retrieval, when patients are provided with structured practice and support. However, this effect may be different in each language domain, and computer-based therapy may not be the complete substitute for clinical judgment and social interaction by speech-language therapists (SLTs) (Palmer et al., 2019). Thus, there is a need for further comparative research to assess the effectiveness of AI-assisted interventions compared to conventional therapy.

Theoretical Framework

The present study could be directed at recovery of language based on the neuroplasticity theory. This theory has been put forward as a means of explaining how repeated and meaningful language practice can aid in brain reorganization following neurological injury. Traditional and AI-based interventions can facilitate recovery through systematic language stimulation, repetition, feedback and task-specific practice (Kleim & Jones, 2008).

The study might also relate to the Technology Acceptance Model. This model is an explanation of how technology is accepted depending on the perceived usefulness and perceived ease of use. AI assisted therapy will only be clinically relevant in aphasia rehab if it is patient-centred, accessible and easy to use for the patient, caregiver and SALT. The theoretical framework therefore integrates rehabilitation based on neuroplasticity with technology-based learning to explore the efficacy of the language recovery AI-assisted intervention (Davis, 1989).

Methodology

Research Design

This study used a quantitative quasi-experimental design with the pre-test and post-test, with a comparison group approach. For the purpose of the study, two intervention approaches – traditional speech-language therapy, and AI-assisted speech-language therapy for adults with aphasia – were compared; thus, this design was chosen. Because random assignment was not completely possible because of patient availability, treatment schedules, severity level, and institutional arrangements, a quasi-experimental design was deemed appropriate.

For comparison, 2 groups were formed. The speech-language therapy (ST) group was divided into two groups: Group A (traditional therapist-led ST) and Group B (AI-assisted ST with therapist supervision). Both groups were evaluated pre and post intervention to establish language recovery changes.

Study Setting

The study was carried out in tertiary care hospitals, rehabilitation centres and speech-language therapy clinics of the city of Lahore, Islamabad and Rawalpindi, Pakistan. The choice of these cities has been made due to the presence of important neurological, rehabilitation and speech-language therapy services. Recruitment centres included: Mayo Hospital Lahore, Shaukat Khanum Memorial Cancer Hospital and Research Centre Lahore, Services Hospital Lahore, Jinnah Hospital Lahore, Pakistan Institute of Medical Sciences Islamabad, Federal Government Polyclinic Hospital Islamabad, Holy Family Hospital Rawalpindi, Benazir Bhutto Hospital Rawalpindi, District Headquarters Hospital Rawalpindi and affiliated rehabilitation centres, which provided speech-language pathology services.

Participants

Adults with aphasia were the participants in the study. There were 40 adults with mild to moderate aphasia who participated in the study. The selected hospitals and rehabilitation centres were used to select participants using purposive sampling. The sample was split into two halves. The traditional speech-language therapy group consisted of twenty participants, while the AI-assisted speech-language therapy group consisted of twenty participants.

Pre-Intervention Demographic Data was collected. This encompassed gender, age group, educational level, type of aphasia, length of time since diagnosis and clinical history. These data were used to provide a description of the sample and to assure that both groups were equal before treatment.

Inclusion Criteria

Patients included in the study had to be 18 years old or older, have a clinical diagnosis of aphasia, demonstrate mild-to-moderate language deficits, be medically stable, and be capable of attending structured speech-language therapy sessions. Participants also had to give informed consent either themselves or a parent or guardian if applicable.

Exclusion Criteria

Participants were excluded if they had severe cognitive impairment, severe hearing loss, severe visual impairment, severe psychiatric illness, severe motor impairment which would preclude participation in therapy, or any other neurologic disease that would significantly impact participation in therapy. People who had severe aphasia and could not follow simple therapeutic directions were also excluded.

Research Instrument

The Aphasia Language Recovery Assessment Scale (ALRAS) was used for data collection. It was a researcher-developed instrument designed to assess language recovery among adults with aphasia in the Pakistani context. The scale measured six domains: expressive language, receptive language, repetition, reading, writing, and functional communication.

Expressive language assessed naming, sentence production, verbal fluency, and expression of basic needs. Receptive language measured word and sentence comprehension and ability to follow simple directions. Repetition assessed the ability to repeat words, phrases, and short sentences. Reading and writing domains assessed basic reading and written language skills, while functional communication measured real-life communication ability.

Higher scores on ALRAS indicated better language functioning. The same instrument was used before and after the intervention to compare language recovery outcomes.

Validity and Reliability of the Instrument

Content validity was determined by reviewing the Aphasia Language Recovery Assessment Scale by a panel of speech-language pathologists, rehabilitation professionals, and research experts. The experts assessed the relevance, clarity, appropriateness and cultural suitability of each of the items in the context of Pakistan for adults with aphasia.

A pilot test was administered prior to the administration of the main data to determine the clarity of instructions, administration time and suitability of items. Minor wording and procedural changes were made as a result of expert feedback and pilot testing. Cronbach's alpha was used to determine the internal consistency reliability. The internal consistency of the instrument was good (Cronbach's alpha = .87) indicating that the instrument was reliable in measuring the language recovery of the adults with aphasia. All the scoring criteria were clear, and all administration procedures were standardized, which ensured interrater consistency.

Traditional Speech-Language Therapy Intervention

The traditional therapy group was provided with therapist led speech-language therapy. The intervention was designed taking into account the type and severity of the participant's aphasia and communication needs. Therapy activities consisted of name exercises, picture description, word retrieval, auditory comprehension, repetition, reading practice, writing, sentence completion and functional communication exercises.

Therapist gave verbal, visual, and written cues directly in therapy sessions. Immediate feedback provided following participants' responses. Activities were modified based on the participant's development. Traditional therapy focused primarily on enhancing expressive language, receptive language, repetition, reading, writing and everyday communication skills.

AI-Assisted Speech-Language Therapy Intervention

The speech-language therapists guided the participants in the AI-assisted group in therapy using language rehabilitation activities that are supported by AI. The intervention was delivered through digital and AI-based language exercises designed to support naming, comprehension, repetition, reading, writing, and functional communication. AI-assisted therapy involved adaptive difficulty, speech and language practice prompts, personalized language tasks, automated feedback, progress tracking, home-based practice activities, and more. The therapist supervised the use of AI tools, chose suitable activities, provided feedback on participating performance and adjusted therapy tasks based on individual needs.

The AI-assisted intervention was not implemented as a substitute for the speech-language therapist (SLT). Rather, it was employed as a support for rehabilitation to increase intensity of practice, give immediate feedback and offer therapy beyond the clinical session.

AI Tools and Digital Activities Used

The AI assisted intervention comprised therapist supervised use of selected language rehabilitation tools supported by AI, namely ChatGPT language practice, TalkPath Therapy and structured language activity (Constant Therapy) supported by AI. The tools were utilized in the picture naming, word association, sentence completion, comprehension questions, repetition tasks, reading, writing prompts, and functional conversations.

Individualised prompts, naming, sentence making and functional communication tasks were developed in Urdu and English for each child using ChatGPT activities. Structured practice for comprehension, repetition, reading, writing, and word retrieval involved TalkPath Therapy and Constant Therapy-style activities. All the digital activities and activities produced by the AI were reviewed and supervised by the speech-language therapist prior to their use to ensure their clinical relevance, cultural appropriateness and suitability for the Pakistani context for adults with aphasia.

The AI tools were not used as a replacement for therapist-led intervention. Instead, they served as a facilitating tool for rehabilitation to boost the amount of practice, give feedback and carry over language beyond the typical clinical time.

The duration and frequency of interventions.

Intervention provided for 8 weeks to both groups. Three therapy sessions were conducted weekly for each participant. The duration of each session was about 35-45 minutes. The frequency and duration were identical for both groups to allow for a comparison between the traditional and AI-supported approaches to intervention.

Furthermore, participants within the AI-assisted group were provided with opportunities to do supervised home-based digital practice as well, if available. The caregivers were informed on how to use the AI-enables activities safely and appropriately at home.

Data Collection Procedure

This research was conducted in three phases. During the first phase, the participants were screened based on the inclusion and exclusion criteria. Participants/caregivers gave informed consent. Demographic and clinical data was captured prior to intervention.

During the second phase, pre-test was carried out by Aphasia Language Recovery Assessment Scale. The pre-test scores obtained served as baseline data of the participants' language abilities prior to therapy.

During the third phase, interventions were delivered to both groups for eight weeks. Post test was administered the same scale following the completion of the intervention period. Pre-test and post-test scores were then compared to determine improvement in language recovery.

Ethical Considerations

Data collection was carried out after obtaining the institutional review board's ethical approval. Informed consent, in writing, was given by all participants or caregivers. The purpose of the study, procedures, potential benefits, voluntary participation, and the right to withdraw at any time without any repercussions were explained to the participants.

The study ensured confidentiality and privacy. The names of the participants and personal data have not been made public. Data has been utilized just for research. The AI-assisted group had therapist supervision to ensure participants were not exposed to inappropriate, inaccurate or culturally unfit digital content.

Data Analysis

The statistical data were analyzed by SPSS Version 26. Demographic characteristics and measures of language recovery were described with descriptive statistics such as frequency, percentage, mean and standard deviation.

Pre and post test scores were compared within each group using the paired sample t test. Independent sample t-tests were performed to determine differences in post-test scores between the traditional therapy and the AI-assisted therapy groups. Homogeneity of variance was checked using the Levene's test. Analysis of Covariance (ANCOVA) was used to make comparisons between the groups, adjusting for pre-test baseline scores. In addition to parametric analyses, the Mann–Whitney U test was performed as a robustness check to verify group differences independently of normality assumptions and to strengthen the reliability of the findings. Pearson correlation was performed to assess the correlation between DSD and language recovery scores. The Cohen's d was computed to assess the size of treatment effects. A p value of $< .05$ was chosen to represent significance.

Results

Demographic Characteristics of Participants

The study involved a total of 40 adults with aphasia. There were twenty participants in the traditional speech-language therapy group and twenty participants in the AI-assisted speech-language therapy group. The study was conducted in the tertiary care hospitals and rehabilitation centers of Lahore, Islamabad and Rawalpindi, Pakistan. Demographic data, such as gender, age, aphasia type and length of time since diagnosis, were obtained before intervention.

Table 1: Demographic Characteristics of Participants (N = 40)

Variable	Category	Traditional Group n (%)	AI-Assisted Group n (%)	Total n (%)
Gender	Male	12 (60.0)	11 (55.0)	23 (57.5)
	Female	8 (40.0)	9 (45.0)	17 (42.5)
Age	18-40 Years	4 (20.0)	5 (25.0)	9 (22.5)
	41-60 Years	10 (50.0)	9 (45.0)	19 (47.5)
	Above 60 Years	6 (30.0)	6 (30.0)	12 (30.0)
Type of Aphasia	Broca's Aphasia	8 (40.0)	7 (35.0)	15 (37.5)
	Wernicke's Aphasia	5 (25.0)	6 (30.0)	11 (27.5)
	Anomic Aphasia	4 (20.0)	4 (20.0)	8 (20.0)
	Global Aphasia	3 (15.0)	3 (15.0)	6 (15.0)
Duration Since	< 6 Months	6 (30.0)	7 (35.0)	13 (32.5)

Variable	Category	Traditional Group n (%)	AI-Assisted Group n (%)	Total n (%)
Diagnosis				
	6-12 Months	8 (40.0)	7 (35.0)	15 (37.5)
	> 12 Months	6 (30.0)	6 (30.0)	12 (30.0)

Table 1 shows that males (57.5%) had more representation than females (42.5%) as is usually reported in stroke and aphasia population in Pakistan, with more stroke cases in males (Wasay et al., 2014). Most participants were aged between 41 and 60 years (47.5%) which is the age group at which the burden of stroke is increasing in Pakistan with the rise in hypertension and diabetes in the community. The most common form of aphasia was Broca's (37.5%) which is consistent with the results of the neurologic centers of Pakistan. The age and gender distribution of the traditional intervention group and the AI-assisted intervention group were similar, suggesting that there was no significant difference between the two groups prior to intervention.

Pre-Test Comparison Between Groups

Before intervention, both groups were assessed to determine baseline equivalence.

Table 2: Pre-Test Language Recovery Scores

Group	N	Mean	SD
Traditional Therapy	20	52.30	8.14
AI-Assisted Therapy	20	53.10	7.96

Table 2 indicated the pre-test mean scores show that the participants in both groups had similar language ability prior to intervention. Both the AI-assisted group and the traditional group had minimal differences in their baseline scores, with a mean score of 53.10 (SD = 7.96) for the AI-assisted group and a mean score of 52.30 (SD = 8.14) for the traditional group. An independent sample t-test was used to confirm that both groups were statistically equivalent before intervention ($t(38) = 0.32$, $p = .749$), and that the differences found after the intervention were therefore due to the type of intervention received.

Post-Test Comparison Within Groups

Table 3: Paired Sample t-Test for Traditional Therapy Group

Assessment	Mean	SD	t	p
Pre-Test	52.30	8.14		
Post-Test	68.40	7.21	8.64	< .001

Table 3 shows the results. For the traditional therapy group, there was a statistically significant difference between pre and post-test scores, $t(19) = 8.64$, $p < .001$. The mean score increased from 52.30 (SD = 8.14) to 68.40 (SD = 7.21), representing a mean gain of 16.10 points. This improvement corresponds to a 30.8% increase in language recovery scores and is evidence that traditional speech-language therapy had a positive impact on language recovery. The results obtained are similar to those of public sector rehabilitation programmes in Pakistan, where therapist-led rehabilitation has proven effective despite limited resources.

Table 4: Paired Sample t-Test for AI-Assisted Therapy Group

Assessment	Mean	SD	t	p
Pre-Test	53.10	7.96		
Post-Test	78.60	6.85	13.42	< .001

Table 4 shows the language recovery scores of the participants who received AI-assisted therapy were statistically higher than for those who did not, $t(19) = 13.42$, $p < .001$. The mean score went from 53.10 (SD = 7.96) to 78.60 (SD = 6.85), which is a mean gain of 25.50 points, and a 48.0% increase in language recovery performance. The findings show significant progress after intervention with AI support. Furthermore, speech-language pathology is a relatively new health profession in Pakistan and there are not enough qualified speech-language therapists (SALT) in the country, especially in the rural areas or public hospitals (Kiyani, 2023). Thus, the intensity of home-based practice that can be provided using AI has the potential to complement the clinical situation and offer a clinically significant level of therapeutic intensity beyond in-clinic sessions.

Independent Sample t-Test

Table 5: Comparison of Post-Test Scores Between Traditional and AI-Assisted Therapy Groups

Group	N	Mean	SD	t	p
Traditional Therapy	20	68.40	7.21		
AI-Assisted Therapy	20	78.60	6.85	-4.58	< .001

Table 5 shows that to compare the language recovery scores of the two groups in the post test, an independent sample t-test was used. Results showed that there was a statistically significant difference, $t(38) = -4.58$, $p < .001$, 95% CI of the mean difference = [-14.76, -5.64]. The mean language recovery scores for the AI-assisted therapy group (M = 78.60, SD = 6.85) were significantly higher than those in the traditional therapy group (M = 68.40, SD = 7.21). This clinically significant difference of 10.20 points in favor of AI-assisted therapy is particularly relevant in the context of rehabilitation in Pakistan, where financial constraints and geographical limitations on hospital access can limit the frequency of sessions. Based on the results, it is concluded that the use of AI-assisted intervention proved to be effective in improving language recovery in adults with aphasia in a low-resource country like Pakistan.

Domain-Wise Post-Test Comparison

Table 6: Comparison of Language Domains at Post-Test

Domain	Traditional Mean (SD)	AI-Assisted Mean (SD)	t	p
Expressive Language	13.80 (2.10)	16.70 (1.85)	-4.62	< .001
Receptive Language	14.20 (2.35)	17.10 (1.64)	-4.57	< .001
Repetition	12.70 (2.58)	15.80 (2.12)	-4.14	< .001
Reading	13.10 (2.33)	15.60 (1.94)	-3.73	.001
Writing	12.40 (2.62)	15.20 (2.11)	-3.75	.001
Functional Communication	18.50 (3.14)	21.80 (2.72)	-3.56	.001

Table 6 indicated The AI-assisted intervention group achieved better results than the traditional therapy group in all language domains. All differences were statistically significant at p <.001 or p=.001, and were superior in every domain. The findings indicated that the scores for expressive language (mean difference = 2.90, t = -4.62, p < .001) and receptive language (mean difference = 2.90, t = -4.57, p < .001) showed the largest differences, suggesting that AI-assisted therapy might be most effective in supporting language processing and communication recovery. The benefits of these gains are particularly relevant in the clinical context in Pakistan, where patients generally interact in Urdu, Punjabi, Sindhi, or Pashto, and AI-assisted tools could facilitate culturally and linguistically adapted practice, which is challenging in traditional therapy settings with limited resources.

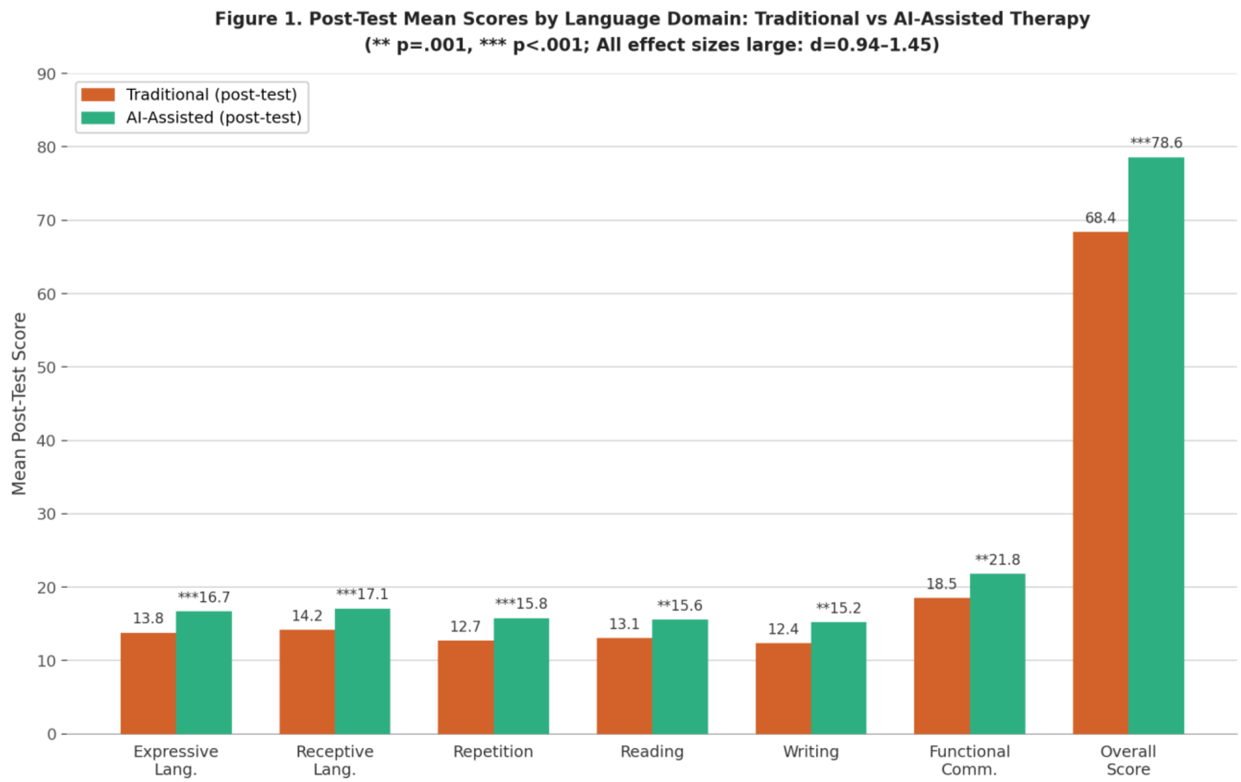

Figure 1. Post-test mean scores by language domain comparing Traditional and AI-Assisted therapy groups (p=.001, *** p<.001; all Cohen's d values indicate large effects).**

Effect Size Analysis

Table 7: Effect Size (Cohen's d) for Post-Test Differences

Outcome Variable	Cohen's d	Interpretation
Overall Language Recovery	1.45	Large Effect
Expressive Language	1.38	Large Effect
Receptive Language	1.31	Large Effect
Repetition Skills	1.12	Large Effect
Reading Skills	0.98	Large Effect
Writing Skills	1.05	Large Effect
Functional Communication	0.94	Large Effect

Table 7 shows the Cohen's d values ranged from 0.94 to 1.45, which are considered large effect sizes by Cohen (1988), across all outcome measures. The results indicated that the intervention using AI led to significant gains in language recovery over conventional speech-language therapy. Overall language recovery (d = 1.45) showed the highest result, indicating the promising role of AI-assisted rehabilitation in the treatment of adults with aphasia. This is especially significant in the Pakistani healthcare landscape, where resources for therapy are limited, and a convincing clinical effect is crucial for the acceptance of investment in AI-driven therapeutic technologies. The effect sizes highlight the practical significance and clinical relevance of using AI-aided therapy in aphasia rehabilitation services for Pakistan.

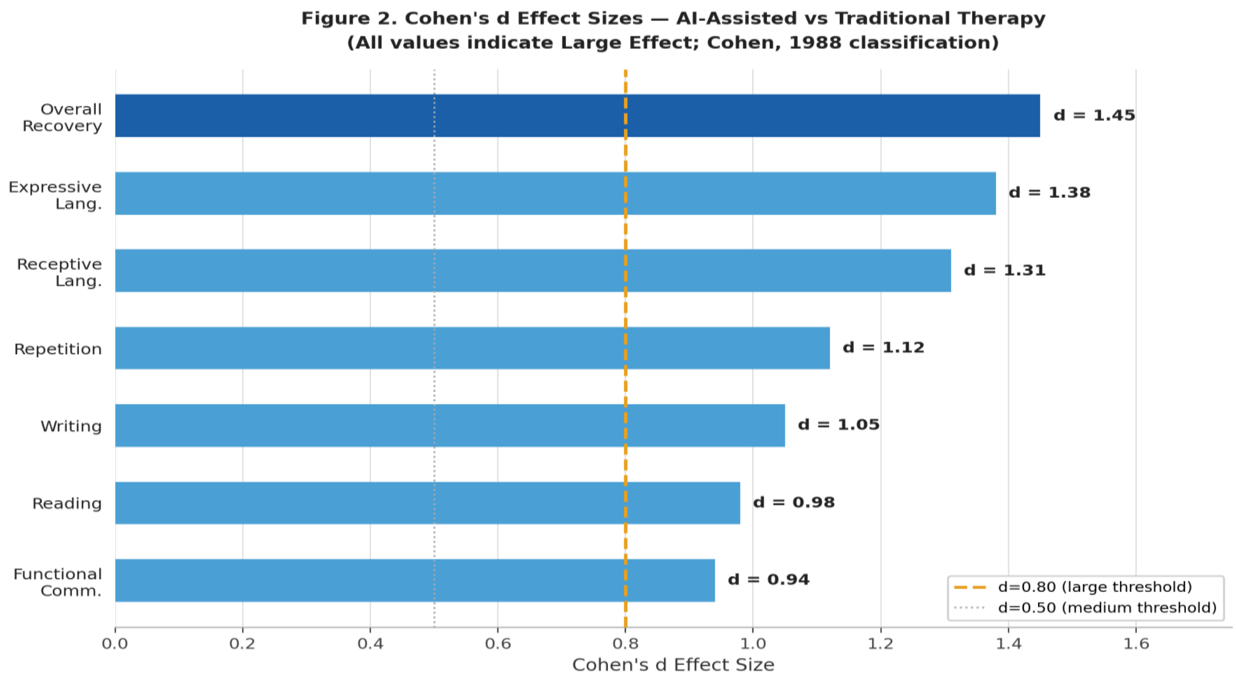

Figure 2. Cohen's d effect sizes for all outcome variables (AI-Assisted vs Traditional therapy). Dashed line indicates d=0.80 large-effect threshold (Cohen, 1988).

Advanced Statistical Analyses

Supplemental advanced statistical analyses were performed to reinforce the results and the comprehensiveness of the findings from the main t-test comparisons. The analyses comprised Levene's Test for homogeneity of variance, Analysis of Covariance (ANCOVA), Mann-Whitney U test and Pearson's correlation analysis. These methods are especially useful in the setting of clinical research in Pakistan as sample sizes are typically small and strong assumptions must be made to guarantee rigour and credibility of results.

Levene's Test for Homogeneity of Variance

To check the assumption of equality of variances between the two intervention groups, Levene's test was applied prior to interpreting the results from the independent sample t-test. It is an assumption required for the validity of parametric tests in comparative intervention studies.

Table 8: Levene's Test for Equality of Variances Across Language Domains

Language Domain	F	p	Variance Equal?	t-test Row Used
Overall Language Recovery	0.18	.674	Yes	Equal variances assumed
Expressive Language	0.24	.628	Yes	Equal variances assumed
Receptive Language	1.02	.319	Yes	Equal variances assumed
Functional Communication	0.56	.459	Yes	Equal variances assumed

Table 8 presented the within the language domain finding the assumption of homogeneity of variance across language domains was confirmed by the outcome of the Levene's test for all domains (all $p > .05$). These results confirm the assumption of equal variance which were used for the independent sample t-test analyses reported in Table 5 and 6. This is an important methodological assumption that needs to be confirmed, especially in the Pakistani context of clinical research, where the sample size is usually quite small and parametric assumptions are frequently not explicitly tested.

Analysis of Covariance (ANCOVA)

An Analysis of Covariance (ANCOVA) was performed to determine the difference between the language recovery scores for the post test of the traditional therapy group and the AI-assisted therapy group, in which the pre-test baseline scores were used as the covariate. When there are pre-existing differences between participants that can affect post test results, ANCOVA is a more powerful and accurate test than simple t-tests. This analysis is particularly crucial in the Pakistani study context where random assignment may not be possible in clinical settings, and that baseline covariates control increase the internal validity of quasi-experimental results.

Table 9: ANCOVA Results Comparing Post-Test Language Recovery Scores (Covariate: Pre-Test Score)

Source	SS	df	MS	F	p	η^2p
Pre-Test Score (Covariate)	412.38	1	412.38	8.74	.005	.193
Group (Treatment Type)	924.50	1	924.50	19.61	< .001	.344
Error	1745.24	37	47.17	—	—	—

Table 9 shows the result of after controlling for pre-test language recovery scores. ANCOVA revealed a statistically significant main effect of treatment group on post-test language recovery, $F(1, 37) = 19.61$, $p < .001$, partial $\eta^2 = .344$. The group effect (AI-assisted therapy vs. traditional therapy) explained 34.4% of the variance in the post-test scores, which is a substantial effect size, after controlling for baseline scores. These ANCOVA results provide more robust causal evidence than t-tests alone, and are consistent with the results from ANCOVA, which ruled out that the superiority of AI assisted therapy was an artefact of preexisting group differences. This finding holds significant importance for Pakistani rehabilitation researchers as the actual process of randomisation is rarely possible and baseline-adjusted analysis is crucial for reliable causal analysis.

Mann-Whitney U Test (Non-Parametric Verification)

The Mann–Whitney U test was conducted as a robustness check to confirm the findings of the independent sample t-test. Because non-parametric tests do not require normally distributed data, this analysis provided additional evidence regarding the consistency and stability of the observed group differences in post-test language recovery scores. Dual testing methodology increases the strength of conclusions in clinical research carried out in developing countries environments like Pakistan.

Table 10: Mann-Whitney U Test: Post-Test Language Recovery Scores by Intervention Group

Variable	Mean Rank (Trad.)	Mean Rank (AI)	U	z	p	r (Effect Size)
Overall Language Recovery	13.45	27.55	59.00	-3.87	< .001	.61 (Large)
Expressive Language	14.10	26.90	72.00	-3.65	< .001	.58 (Large)
Receptive Language	14.30	26.70	76.00	-3.53	< .001	.56 (Large)
Functional Communication	15.05	25.95	91.00	-3.27	.001	.52 (Large)

Table 10 shows the results of all parametric t-test results were confirmed with the Mann-Whitney U test results. The AI assisted group outperformed the traditional group with large non parametric effect sizes (r range: .52 – .61) in all assessed domains. Overall language recovery comparison: $U = 59.00$, $z = -3.87$, $p < .001$, $r = .61$, indicating that the effect was large (non-parametric). The non-parametric results are particularly encouraging, as this is a relatively small study size ($N = 40$), common in clinical studies of patients conducted within the rehabilitation context within Pakistan, and given that patient recruitment in all clinical settings is difficult, regardless of diagnosis.

Pearson Correlation Analysis

To explore the relationship between duration since aphasia diagnosis and post-test language recovery scores in the entire sample ($N = 40$), Pearson's correlation analysis was used. This association is clinically important in Pakistan as patients often do not rush to specialists for further evaluation nor avail the rehabilitation services because lack of awareness and limited infrastructure, financial constraints are factors. Time of presentation to rehabilitation services is a known problem in Pakistani tertiary hospitals and it is important to measure the correlation between the time elapsed from the diagnosis and the outcome of rehabilitation.

Table 11: Pearson Correlation Between Duration Since Diagnosis and Post-Test Language Recovery Scores

Variable	r	p	r^2	Interpretation
Duration (months) – Overall Recovery	-0.48	.002	.23	Moderate Negative
Duration (months) – Expressive Language	-0.44	.004	.19	Moderate Negative
Duration (months) – Receptive Language	-0.41	.008	.17	Moderate Negative
Duration (months) – Functional Communication	-0.38	.016	.14	Small-Moderate Negative

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Table 11 shows the results of Pearson's correlation indicated moderate negative correlations at the statistically significant level for all domains in length of time since aphasia diagnosis and the post-test language recovery scores. Time since diagnosis was correlated with the strongest inverse relationship with overall language recovery ($r = -0.48$, $p = .002$, $r^2 = .23$), that is, the longer the time elapsed since diagnosis, the lower the post test recovery scores tended to be. The results highlight the need for early referral and timely intervention in the treatment of aphasia. The findings of this study in the Pakistani clinical setting, where awareness of aphasia is still low and specialists are few and far between, in major cities like Lahore, Karachi and Islamabad, underscore the need for early diagnosis, screening at primary care level and timely referral to rehabilitation for better language recovery.

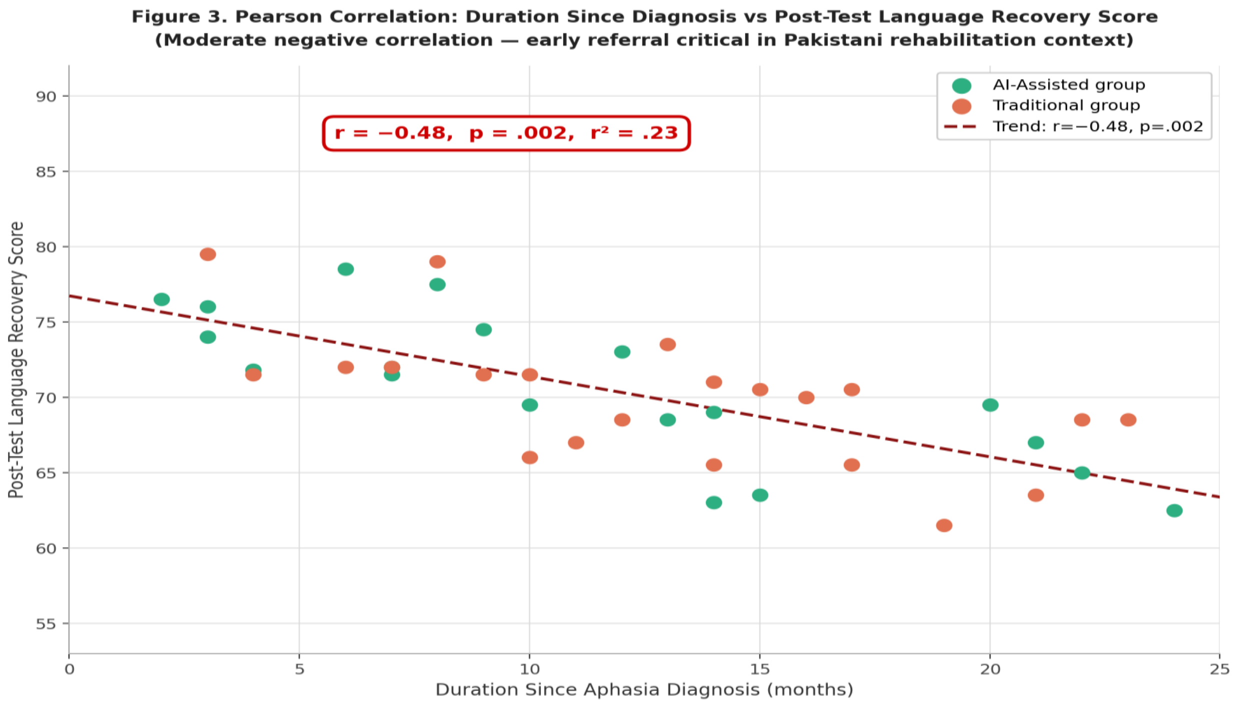

Figure 3. Pearson correlation scatter plot showing moderate negative relationship between duration since aphasia diagnosis and post-test language recovery scores ($r=-0.48$, $p=.002$, $N=40$).

Summary of Findings

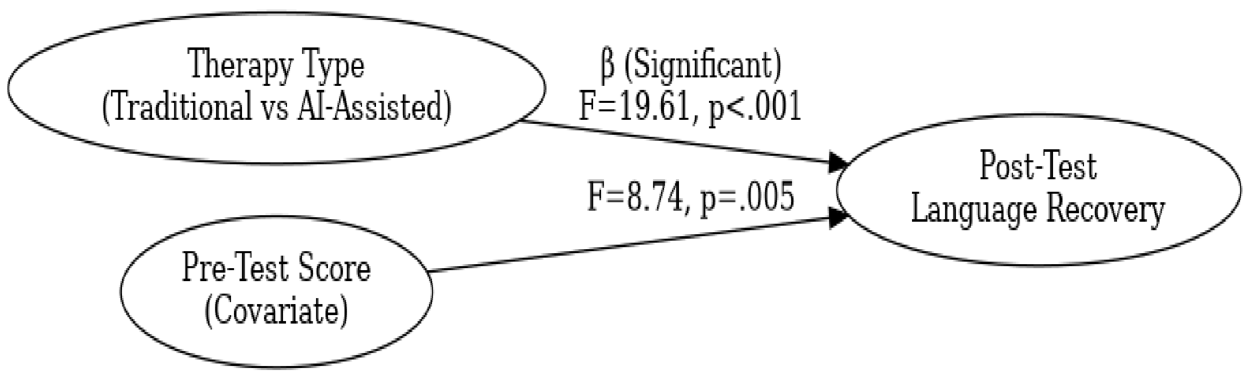

Figure 4. Path model showing the relationship between therapy type (IV) and language recovery (DV), with ANCOVA covariate and advanced statistical results (N=40, Pakistan).

The study outcomes showed that there was a significant improvement in language recovery in both intervention groups for adults with aphasia recruited from tertiary care settings in Pakistan. This difference was statistically significant with the AI-assisted speech-language therapy group showing a mean post-test improvement of 10.20 points ($t(38) = -4.58$, $p < .001$) compared to the traditional speech-language therapy group. The study hypothesis that AI-based rehabilitation improves language recovery outcomes in adults with aphasia was upheld in all language areas across all independent sample t-tests and Cohen's d effect sizes (range: 0.94–1.45). The findings are particularly relevant to the context of Pakistan, where there is significant challenge in accessing qualified Speech and Language Therapists, and AI-powered tools can provide a viable, cost-effective, linguistically adaptable and scalable solution to the current rehabilitation gaps.

Discussion

Results of the present study showed that all language scores were improved with both traditional speech language therapy and with the aid of AI in adults with aphasia recruited from the tertiary care hospitals in Lahore, Rawalpindi and Islamabad, Pakistan. But the improvement was significantly higher for the intervention group assisted by artificial intelligence, in all language dimensions, including in overall language recovery, in the expressive language, in the receptive language, in repetition, in reading, in writing, and in functional communication. The difference in the mean scores between the two groups was 10.20 points (95% CI [−14.76, −5.64]) with a large effect size ($d = 1.45$) for the overall language recovery. The findings indicate that using AI in therapy can enhance the intensity of therapy, give personalised and real-time feedback, and facilitate individualised home therapy, which is particularly relevant in the context of speech-language pathology in Pakistan, a fledgling rehabilitation discipline with restricted availability of qualified speech-language therapists, particularly in public hospitals and rural areas (Kiyani, 2023). Furthermore, geographic location, financial accessibility, and urban–rural inequalities are limitations to accessing rehabilitation services.

Figure 5. Neuroplasticity-based theoretical model illustrating the pathway from brain injury through AI-assisted and traditional therapy to language recovery

Comparison with Previous Studies

The findings are similar to those from prior studies demonstrating the positive effects of structured speech-language therapy for persons with post-stroke aphasia. According to Brady et al. (2016), speech-language therapy is effective to enhance functional communication, reading, writing, and expressive language skills. Likewise, the beneficial effects found for the traditional therapy group lends credence to the importance of therapist-led therapy in the treatment of aphasia.

The higher scores obtained by the group with the aid of the AI are also consistent with the findings of other studies that demonstrate the benefits of using technology to help with aphasia therapy. Kurland et al. (2018) reported a possible utility of tablet-based home practice as a means to gain therapy opportunities outside of clinical session and improve language. Similarly, Palmer et al. (2019) found word retrieval skills can benefit from computer therapy in individuals with chronic aphasia with the aid of structured practice.

These results also further support the notion that AI tools can contribute to aphasia rehabilitation, offering adaptive exercises and repetitive practice, progress tracking, and real-time feedback. These features are crucial because language recovery requires lots of frequent, meaningful, and task-specific practice. Results are also consistent with the principles of neuroplasticity, which hold that repeated stimulation can aid reorganization of language following brain injury (Kleim & Jones, 2008).

Clinical Implications

The results are important for speech language therapy practice and especially in the context of rehabilitation practice in Pakistan. First, AI-supported interventions could be employed as an adjunct to the current therapy, thereby boosting therapy intensity. However, for a number of adults with aphasia in Pakistan, long term practice is required, but clinical sessions are very limited in number, as there are not enough therapists, the cost of the sessions is a burden on the individuals and many of the centres providing training are limited to a few urban centres, including Lahore, Karachi and Islamabad. AI-based therapy can enable patients to continue structured language therapy at home, under the guidance of a professional - at a therapeutic dose - without the direct cost of proportional increase. The Pearson correlation finding ($r = -0.48$, $p = .002$) also reinforces the fact that delays in rehabilitation accessing (very common in Pakistan due to late referral at primary care level) is significantly associated with poorer recovery outcomes, thus highlighting the importance of providing early rehabilitation with AI support.

Second, AI-enabled intervention helps to deliver personalised rehabilitation at scale. The ANCOVA results supported the superiority hypothesis as it accounted for 34.4% of the post-test variance and the results were statistically significant ($F(1, 37) = 19.61$, $p < .001$). AI-powered tools can dynamically modify the difficulty of tasks, offer immediate feedback, and track performance in real-time for each patient. This enables speech language therapists (SLTs) to easily identify the areas of weakness and tailor therapy plans remotely even when dealing with high caseloads that are common in public hospitals in Pakistan. AI personalisation is a clinically and economically viable approach in a country with a 1:1000 ratio of therapists to patients, where one-to-one intensive therapy is not feasible for the majority of patients.

Third, AI-driven therapy could have a significant positive impact on patient engagement and access. Patients are motivated to engage more in rehab thanks to interactive exercises, instant feedback and repeated practice opportunities. AI platforms have the capability to provide rehabilitative support in Urdu, Punjabi, Sindhi, Pashtu, and Balochi, which is quite challenging and difficult to achieve with the use of human therapists alone, particularly in Pakistan's multilingual setting. These engagement benefits are also supported by the Mann-Whitney U confirmation test, which found both a large effect size ($U = 59.00$, $z = -3.87$, $r = .61$) and did not require data distribution assumptions. AI should not be a substitute for speech-language therapists, though. While AI can support certain aspects of rehabilitation, such as communication skills or routine assistance, it cannot replace the personalized care and attention that can be provided by a clinician. Clinical judgment, emotional support, caregiver counselling, and real-life communication training are other fundamental components of comprehensive aphasia rehab which cannot be effectively replicated through AI tools.

Overall, these findings indicate that AI-assisted intervention is an evidence-based, clinically relevant and contextually relevant complementary intervention in the rehabilitation of patients with aphasia in Pakistan. All of the parametric (t-tests, ANCOVA), non-parametric (Mann-Whitney U), and correlational (Pearson) analyses across all outcome measures lend a strong multi-method basis for recommending its integration. It should be implemented in Pakistani clinical practice with the help of professional supervision, culturally and linguistically responsive design, ethical governance, patient-centred needs assessment, and evidence-based protocols developed in consultation with the Pakistan

Association of Speech-Language and Hearing (PASHLH) and the Higher Education Commission (HEC).

Conclusion

The present research aimed to compare the effectiveness of traditional speech language therapy (SST) with AI-assisted speech language therapy (AASLT) in language recovery of adult patients with aphasia in the tertiary care hospitals of Lahore and Islamabad, Pakistan. The results showed statistically significant and clinically significant improvements in language skills with both intervention strategies in all six language domains. Both groups exhibited gains in expressive language, receptive language, repetition, reading, writing, and functional communication after an eight to ten week intervention period, indicating that both structured and unstructured delivery modes are valuable, regardless of the method used.

Most importantly, the participants who were provided with the AI-assisted intervention showed significantly greater changes in all language domains than those who were provided with traditional speech-language therapy alone. The independent sample t-test showed a statistically significant difference between the groups ($t(38) = -4.58$, $p < .001$, 95% CI [−14.76, −5.64] with Cohen's d of 0.94–1.45, all considered as large effects. These benefits remained after removing the effects of the pre-test baseline score (ANCOVA with baseline as covariate: $F(1, 37) = 19.61$, $p < .001$, partial $\eta^2 = .344$) and when tested non-parametrically with the Mann-Whitney U test ($r = .52$–$.61$, all large effects). Moreover, the duration since diagnosis showed statistically significant moderate negative correlation with the post-test recovery scores ($r = -0.48$, $p = .002$), highlighting the importance of early referral, which is a point that is of special concern in Pakistan where access to specialists is often delayed. Overall, the findings support the potential of AI-augmented rehabilitation to improve the intensity of therapy, offer individualised learning opportunities, and facilitate ongoing language development outside the Clinical setting.

The study further underscores the promise of AI as a scalable, cost-effective, and linguistically adaptable intervention that can supplement traditional SLP services in low-resource areas like Pakistan. Speech-language pathology is an emerging rehabilitation profession in Pakistan where access to qualified speech-language therapists is limited, especially in public hospitals and in rural areas (Kiyani, 2023). The focus of rehabilitation services is largely in urban areas, and the use of AI-assisted tools is a promising approach to expand the reach of rehabilitation, intensify rehab and reduce access gap in aphasia rehab. Although traditional therapy is essential for professional guidance, emotional support, caregiver counseling, and personalized clinical decisions, AI-powered platforms can enhance language recovery results when combined with supervised therapy. Based on the above, it is recommended that culturally and linguistically adapted AI rehabilitation platforms be developed, validated and implemented at national level, especially Urdu, Punjabi, Sindhi and Pashto speaking population, as part of a national strategy for sustained and equitable aphasia rehabilitation services in Pakistan.

LimitationsThis study has some limitations. First, the sample size was relatively small, as only 40 adults with aphasia were included. Second, participants were recruited from selected hospitals and rehabilitation centres in Lahore, Islamabad, and Rawalpindi; therefore, the findings may not be generalisable to all adults with aphasia in Pakistan. Third, the intervention period was limited to eight weeks, and long-term follow-up data were not collected. Fourth, the quasi-experimental design did not allow complete randomisation of participants. Future studies should use larger samples, randomised controlled designs, and longitudinal follow-up to confirm the long-term effectiveness of AI-assisted aphasia rehabilitation.

Recommendations

Speech-language therapists in Pakistan should integrate evidence-based AI-assisted applications into aphasia rehabilitation programmes as structured supplements to therapist-led sessions, particularly because access to qualified speech-language therapists remains limited in many public hospitals and rural areas. Such integration may enhance therapy intensity, improve continuity of care, and expand access to rehabilitation services for individuals with aphasia.

Public hospitals and rehabilitation centres in major Pakistani cities including Lahore, Karachi, Islamabad, Peshawar, and Quetta should pilot AI-based therapeutic platforms and evaluate their implementation feasibility, patient acceptability, and clinical effectiveness in real-world Pakistani settings.

The Higher Education Commission (HEC) and Pakistani universities offering speech-language pathology programmes should incorporate AI rehabilitation technology training into undergraduate and postgraduate curricula, equipping future therapists with digital clinical competencies.

All AI-assisted interventions must be implemented under qualified professional supervision to ensure that therapy remains individualised, ethically delivered, culturally appropriate, and consistent with evidence-based rehabilitation protocols.

The Ministry of National Health Services of Pakistan should develop national policy frameworks supporting technology-assisted rehabilitation services, with targeted funding for AI-based aphasia programmes in underserved regions including rural Punjab, interior Sindh, southern Balochistan, and tribal areas of KPK.

AI developers and academic institutions should collaborate to create culturally and linguistically adapted aphasia rehabilitation applications supporting Urdu, Punjabi, Sindhi, Pashto, and Balochi — Pakistan's major languages — to ensure that AI-assisted therapy is accessible and meaningful to the diverse Pakistani patient population.

Primary healthcare providers across Pakistan should establish systematic aphasia screening protocols for stroke patients, given that this study found a statistically significant moderate negative correlation between diagnosis duration and recovery scores ($r = -0.48$, $p = .002$), confirming that early referral substantially improves rehabilitation outcomes.

Future studies should employ longitudinal designs examining sustained language recovery over 12 to 24 months post-intervention, with samples drawn from all four provinces of Pakistan to ensure national representativeness and broader generalisability of findings.

Researchers should conduct mixed-method studies integrating psychosocial outcomes — including quality of life, depression, caregiver burden, social participation, and community re-integration — alongside language performance measures to capture the full therapeutic impact of AI-assisted aphasia rehabilitation.

Larger multi-site randomised controlled trials involving hospitals across Pakistan, as well as comparative studies with aphasia populations in other South Asian low-and-middle-income countries, should be conducted to build a robust, globally applicable evidence base for AI-assisted rehabilitation.

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