INTERNATIONAL JOURNAL OF
SOCIAL SCIENCES BULLETIN
ISSN: (E) 3007-1917 (P) 3007-1909

Volume 4, Issue 2, 2026

EVALUATING AI-BASED LEARNING APPS TO ENHANCE ATTENTION, RECOGNITION, AND MEMORY IN CHILDREN WITH MILD INTELLECTUAL DISABILITIES: A SINGLE-SUBJECT EXPERIMENTAL STUDY

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DOI: https://doi.org/10.5281/zenodo.18721780

Received	Accepted	Published
22 December 2025	06 February 2026	21 February 2026

ABSTRACT
Artificial intelligence (AI) has gained increasing attention in special education for its potential to support individualized learning. This study evaluated the use of AI-based learning applications to enhance attention, recognition, and memory among children with mild intellectual disability (MID) in a government special education school in Punjab, Pakistan. A single-subject A-B-A experimental design was employed. Five children aged 7-14 years participated in a 12-week individualized intervention using Khan Academy Kids and JADE Autism. The researchers developed an observational checklist comprising 25 items to assess attention, recognition, and memory across the baseline, intervention, and withdrawal phases. Data were analyzed using Tau-U effect-size statistics suitable for single-case experimental designs. The results demonstrated statistically significant improvements in attention, recognition, and memory during the intervention phase. Results showed large, significant gains in attention, recognition, and memory during intervention (Tau-U = 0.87-1.00, $p < .001$), with reduced but sustained performance after withdrawal (Tau-U = -0.60 to -0.84, $p < .001$). The results show that AI-based mobile apps are useful teaching tools for improving cognitive skills in children with MID and can be effectively used in special education classrooms.
Keywords: *Artificial Intelligence, Mild Intellectual Disability, Cognitive Skills, AI-Based Applications, Special Education.*

INTRODUCTION

Children with intellectual disabilities have lower-than-average intellectual performance and adaptive behavioral constraints that impair learning and living skills. These students tend to have difficulties with attention, memory, language development, problem-solving, and independent functioning, which adversely affect their academic development (Schalock et al., 2021). Subsequently, children with mild intellectual disability require structured learning in special schools, including simplified content, repetition, and constant feedback tailored to their learning rate (Faiz and Hina, 2024). Nevertheless, most traditional teaching techniques are based on standardized instruction with minimal differentiation; hence, they are not effective in meeting individual learning needs and limit learners' ability to memorize and generalize information.

Technology has become more significant in instruction of special education whether in simple assistive devices or more sophisticated digital technologies. First level technological interventions were mainly concerned with the accessibility and payment, like visual aids and simple computer-based programs aimed at lessening the learning barriers. The tools have over time grown into interactive online applications to facilitate individualized and adaptive learning among the students with varied needs, including those with intellectual disabilities (Alnahdi, 2014). It has been demonstrated that special education instruction can be improved through technology-based instruction, which can increase engagement, offer systematic practice, and facilitate skill acquisition (Faiz & Hina, 2024).

The recent development of artificial intelligence (AI) has broadened the scope of educational technology beyond the customizable, adaptable learning to data-driven, personalized learning. Special education has attracted the attentions of AI-based applications because of their ability to tailor the content, give instant feedback, and modify the education methods according to the learner achievements. These applications can help the teachers since they provide organized activities and learning assistance that can be customized to the needs to children with mild intellectual disabilities (Almarzouq et al., 2025).

Although the introduction of AI-based applications in special education is increasingly becoming more entrenched, there is evident absence of experimental research that depicts their efficacy in enhancing certain cognitive abilities, especially attention, recognition, and memory, in intellectually challenged children. The available literature focuses more on teachers' perceptions of academic performance than on intervention-based research using direct cognitive measures. To address this gap, this research paper evaluates the efficacy of AI-based applications in enhancing attention, recognition, and memory in children with intellectual disabilities using a single-subject experimental design.

Statement of the Problem

Children with ID, due to their limited intellectual capacity, often experience difficulties in attention, recognition, and memory, which affect their learning and daily life. Traditional teaching methods in special education are often not individualized enough to address these difficulties. AI-based educational applications support individualized learning for children. Their application in special education, however, is largely based on assumptions rather than evidence. There are no obvious single-subject experimental investigations of their impact on attention, recognition, and memory.

Significance of the Study

This research will provide experimental data on the performance of AI-based applications for enhancing attention, recognition, and memory in children with intellectual disabilities. It will be added to the diminutive part of single-subject research that emphasizes actual cognitive skill outcomes rather than perception. The results will justify the use of AI tools in special education classrooms. The research will also contribute to teachers and practitioners by providing guidance on structured, technology-supported interventions.

Research Objectives

The objectives of the study to:

1. evaluate AI-based applications in improving attention among children with intellectual disabilities.
2. examine the effectiveness of AI-based applications in enhancing recognition skills among children with intellectual disabilities.
3. assess the effectiveness of AI-based applications in improving memory skills among children with intellectual disabilities.
4. analyze changes in attention, recognition, and memory across intervention phases.

Research Questions

The following were the research questions:

1. What is the effect of AI-based applications on the attention skills of children with intellectual disabilities across intervention phases?

2. To what extent do AI-based learning apps improve recognition skills in children with intellectual disabilities?
3. What changes occur in the memory skills of children with intellectual disabilities following the intervention phases of AI-based applications?
4. To what extent do attention, recognition, and memory skills vary across phases?

Literature Review

Children with mild intellectual disability show below-average intellectual functioning and limitations in adaptive behavior that affect learning and daily skills. They usually have problems with attention, memory, language development, problem-solving, and independent functioning, and they disrupt the academic progress (Elshani et al., 2020; Schalock et al., 2021). The said learners need to be taught systematically in the special-educational setting, with simplified content, repetition, and continuous feedback that matches their pace of learning (Dichaba et al., 2024). Nevertheless, many conventional teaching methods are characterized by a lack of differentiation and standard teaching, which makes them less efficient at meeting the needs of children with a mild intellectual disability and limits their ability to retain and generalize information.

Cognitive Deficits in Intellectual Disabilities

Cognitive skills refer to mental powers which help people to think, learn and information processing. These abilities are attention, recognition, memory, reasoning, and problem-solving and they are of central importance in learning and in day-to-day operations. Cognitive skills in children with intellectual disabilities also tend to develop at a slower rate and may be severely impaired, which influences their concentration, ability to recognize objects or symbols and recall the information they have learned. The aspects of weaknesses may be a barrier to academic development, communication and independent living.

Attention Span

Attention span can be defined as the capacity of someone to be attentive to a particular activity or task without being distracted. It is also an important factor in the learning process because the ability to concentrate on things over time enables learners to adhere to instructions and learning resources and accomplish tasks (Chen & Cui, 2021). Intellectually handicapped children have a short attention span which in turn sometimes influences their performance in school as well as in day-to-day activities. Attention issues can result in unfinished work, incomplete involvement, and problems with the acquisition of new abilities (Jacob et al., 2021).

Recognition

Recognition is a mental ability that entails the capability to be able to name and distinguish objects, symbols, individuals, sounds, or designs depending on past experience. Learning cannot take place without it since it facilitates the tasks to locate letters, numbers, colors, shapes, and memorized words. Intellectually challenged children frequently experience problems of recognition that might interfere with the readiness to read, language development and everyday functional behavior. Lack of recognition skills can impair the ability of a learner to relate the new information to the already familiar knowledge (Eysenck and Keane, 2020; APA, 2023).

Memory

Memory is a core cognitive ability that enables children to receive, retain, and recall information to be used in the future. It facilitates almost all functional areas of learning: reading, problem-solving, language development, and social interaction (Al Saeed, 2021). Memory enables children to relate new information to what they already know to make sense of the surrounding world and to use acquired knowledge in other scenarios (Jamal-Camden, et al., 2024). Gathercole and Alloway (2008) suggest that memory is essential for academic success, particularly in education, because it helps children follow instructions, solve problems, and process information as it comes in. Well-endowed children in memory have increased learning powers, are more likely to remember longer, and perform well in academic and day-to-day life (Klein, 2023).

Artificial Intelligence in Special Education

Artificial intelligence (AI) in special education is the application of data-driven systems that can be changed to adapt learning instructions, automate feedback, and assist decision-making processes to meet diverse learning needs. AI can also be integrated into the classroom practice through learning platforms and mobile applications that can adapt the level of difficulty, suggest the next actions, and give instant feedback depending on the learners. In the recent reviews of AI in special education, the most frequent applications are noted, including personalized learning aids, assistive and accessibility, and analytics to assist teachers track the progress (Hopcan et al., 2022). Simultaneously, these reviews also mention that the evidence base is not homogeneous among disability groups and outcomes and that most of the studies need more robust experimental designs and better reporting.

Artificial Intelligence Learning Applications

Learning applications based on AI usually integrate interactive multimedia activities (visual prompts, audio cues, animations, and touch-oriented activities) with adaptive learning. In the case of student with intellectual disabilities, the applications can prove to be useful, as they can be used to break down content into small steps, give them structured repetition, and provide immediate corrective feedback. Adaptive systems can also decrease cognitive load by made easy decisions and keeping a regular routine but adding difficulty as the performance is upgraded. In addition to its adaptation, several AI-powered apps also come with built-in data logs (e.g. accuracy, time-on-task, response patterns) which can inform teacher planning and individual goal setting. Extended AI-in-education reviews also characterize the personalization and feedback as the fundamental processes according to which AI can be used to improve learning (Liu et al., 2025).

Artificial Intelligence-based Mobile Apps

Mobile app is the type of software that is designed to be executed on a phone, tablet, or touchscreen (Jiao, 2025). The popularity of these apps lies in the fact that the apps are convenient to use and there is an immediate access to various services. They can be of any type: games, calculators, web browsers and educational tools. Majority of the apps are small and specific, which makes them suitable in everyday life. On top of simple use, interactive and personalized learning experiences can also be provided by them, particularly useful in special education. These educational applications can be used by teachers to interact with students and enhance their recognition skills (Beili et al., 2024).

Recent Studies

The studies into AI in special education are growing, recent syntheses tend to report positive trends, but also focus on methodological constraints. To illustrate, a systematic review of the AI in special education literature found that there was increased interest in AI-based instructional and assistive interventions, though inconsistent quality of the studies and more rigorous approaches to evaluation are required (Hopcan et al., 2022). Likewise, a systematic review of AI-based interventions in learners with disabilities expressed the positive results, yet it is mentioned that most of the studies use the broad achievement indicators or lack an experimental design, which complicates making the strong conclusions regarding cause and effect (Panjwani-Charania and Zhai, 2023).

There are also more modern disability-specific findings that AI-based interventions may turn out to be useful, yet, the intensive experimental research and the direct measurements of abilities are needed. As one may note, a recent systematic review published by Brain Sciences discovered that AI-based interventions could potentially positively impact academic and cognitive outcomes of learners with disabilities, but the researchers noted that the current evidence is quite preliminary and requires more intensive designs (Paglialunga & Melogno, 2025). As to the intellectual disability, specifically, the accumulation of empirical studies on the topic of AI-based learning is on the rise, and the results demonstrate better learning performance, especially in the cases where adaptive feedback and guided practice are integrated into the teaching (Alsolami, 2025). However, because many studies in this area prioritize academic outcomes, there remains a

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clear need for intervention research that directly measures core cognitive processes such as attention, recognition, and memory using rigorous single-subject experimental designs.

Research Gaps

Although the use of artificial intelligence (AI)-based applications in special education has increased rapidly, the existing body of research is dominated by descriptive, survey-based, and perception-focused studies. A significant percentage of the literature focuses on the attitude of teachers, how easily AI tools can be used, or how they can be incorporated into the classroom as opposed to assessing the direct instructional effect of AI tools. It has been repeatedly noted in recent reviews that few studies have adopted rigorous experimental or single-subject studies with the potential to prove causal relationships between AI-based interventions and outcomes of learners (Hopcan et al., 2022; Paglialunga and Melogno, 2025). Consequently, there is a lack of evidence on the actual usefulness of AI-based applications especially on the part of learners with intellectual disabilities who need to receive interventions that are organized and evidence-based.

Besides limitations built into design, most of the currently available studies determine results by the use of general academic outcomes or indicators of global performance which can mask results to changes in underlying cognitive processes. Attention, recognition, and memory are cognitive skills, which are the basis of learning and adaptive functioning in children with intellectual disabilities, but identify as little investigated as separate results in AI-based intervention studies. Researchers are now examining cognitive abilities as specific skills and using repeated assessments rather than general achievement tests or subjective judgments (Schalock et al., 2021; Wang et al., 2024). This approach enhances our understanding of changes in individual cognitive skills over time. Hence, experimental studies are necessary that focus on specific cognitive processes, particularly attention, recognition, and memory, to investigate the effects of AI-based applications. This gap will be filled, providing more convincing evidence and supporting more informed decisions in the field of special education (Schalock et al., 2021; Wang et al., 2024).

Methodology

The study employed a single-subject experimental design with A-B-A repeated measurements across pre, during and post-intervention phases to examine the effects of AI-based mobile apps (Khan Academy Kids & JADE Autism) on attention, recognition, and memory in children with mild intellectual disabilities (Cranmer, 2017; Jimenez, 2018). Under this design, the performance of each participant was to be measured at three stages: before the intervention, during the intervention, and after the intervention (Fabrizi & Winston, 2016). Every child was under control, so there was no need to compare one child with another; only to observe individual progress. This methodology was considered suitable due to the small sample and the need to deliver the intervention individually, which is the focus of personalized research in special education (Alqraini, 2017).

The research design used in

Population and Sample

The sample population comprised children with mild intellectual disabilities enrolled in government special education schools in Punjab, Pakistan. The sample size was 05 students aged 7-14 years who were sampled in Government Special Education Centre on 03-Remaining Disabilities, Okara on the basis of specific inclusion criteria. Inclusion criteria are fixed criteria which are used in defining the participants that could take part in a study. They help to make the study valid and goal-oriented by defining the eligibility of the participants (Patino and Ferreira, 2018). Inclusion criteria were as follows: (a) official disability certificate (which proved mild intellectual disability), (b) teacher reports on the problems of attentiveness, (c) the parent permission written consent. The study included only boys; girls were excluded because the selected special education school was gender-segregated. The researchers have examined several articles on the uses of artificial intelligence and have chosen to use mobile applications in the study. The researchers selected the apps based on AI features such as personalization, adaptive content, and feedback. The applications proved user-friendly for educators and learners, significantly enhancing their attention, recognition, and memory.

Procedure for Implementing the Intervention Plan

The intervention was done in 12 weeks with 25 individual sessions. The researcher prepared 10-minute activities during every session where the AI-based tools (Khan Academy Kids and JADE Autism) offered a few short activities, each taking about 2-3 minutes. After the sessions, there was a 5-minute break to minimize fatigue. The applications were used by the students on a tablet under the supervision of the researcher where verbal prompts were minimally used in the instances where they were necessary. Activities that were age-related were chosen so as to focus on attention, recognition, or memory. Attention tasks were tasks that were answered in response to visual or auditory information, recognition tasks were tasks to identify and match stimuli that had been learned and memory tasks to recall sequences or previously tested information. In-app timers were used to track the duration of the tasks and a structured observational checklist to record the performance of the students such as accuracy, independence, and the need to prompt students. All the activities were applied using the Punjab Department of Special Education curriculum guidelines.

Research Instrument for Data Collection

The researchers developed an observational checklist to assess students' cognitive performance using a single-subject A-B-A experimental design. The checklist was made up of 25 distinct and observable tasks that assessed three cognitive domains which include attention, recognition, and memory. Each of the items was rated on the basis of performance scale of 5 points between very high and very low. Data were systematically collected across three phases: baseline (A_1), intervention (B), and post-intervention (A_2). The gap will be closed and will provide more precise evidence that will inform instructional decision-making in special education. Sample items included recalling a sequence of images after a brief delay (memory), matching previously introduced pictures with corresponding words (recognition), and following and repeating simple instructions in the correct order (attention). The special education experts reviewed the checklist and it was developed on the basis of literature that is relevant to the work. Reliability: This was done by replicating observation of the same behaviors using standardized administration procedures at all phases. The single subject A-B-A design enabled making within-participant comparisons by visually evaluating levels, trends, and variability between phases. The adherence to treatment was ensured through adhering to a prepared session plan, applying the AI-based applications every time, and making sure that all of them were equally exposed to the intervention period.

Data Analysis & Interpretation

The analysis of the quantitative data was performed with Tau-U, which is a statistical tool designed best to be applied to studies with one subject and limited sample sizes. The performance scores on both attention, recognition and memory were gathered in three phases, which include pre-intervention, intervention, and post-intervention. Tau-U was used to examine phase-to-phase changes (pre vs. during, pre vs. post, and during vs. post), accounting for baseline trends where necessary. Tau-U values, z-scores, and p-values were calculated using a single-case non-overlap analysis tool. The visual inspection was performed on the baselines, and trend-corrected Tau-U was used for cases with baseline trends. A positive Tau-U value was interpreted as indicating improvement, and a negative value as indicating decline. The p-values were used to assess statistical significance. Performance trend visual inspection was applied in conjunction with Tau-U outcomes to determine when, by which amount, and how long individual gains would persist. Age was reported descriptively to contextualize the findings.

Ethical Consideration

Ethical approval was obtained from the relevant institutional authority, and permission was granted by the administration of the selected government special education school. Written

INTERNATIONAL JOURNAL OF
SOCIAL SCIENCES BULLETIN
ISSN: (E) 3007-1917 (P) 3007-1909

informed consent was obtained from parents and legal guardians of all participants, and confidentiality was maintained throughout the study.

Demographic Distribution

Table 1

Age of the participants

Age	n	%
7-8	1	20%
9-10	1	20%
11-12	1	20%
13-14	2	40%
Total	05	100%

Table 1 depicts the age of the five respondents. There were 7, 8, 9, 10, and 11 age-group participants (20% each), and the 13 and 14 age-group participants (2) (40%). The majority of the sample were participants aged 13-14.

Visual Analysis of Participant 1 Across Cognitive Domains

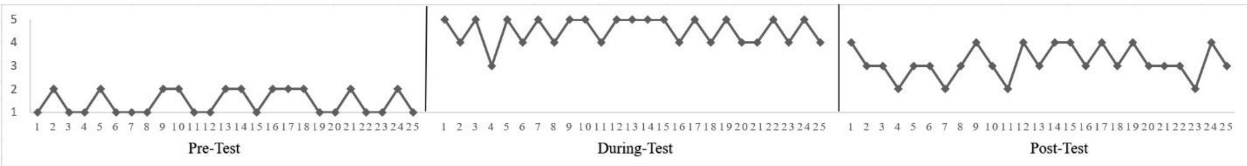

Figure 1

Participant 1's attention performance across pre-test, during-test, and post-test phases.

Figure 1 presents Participant 1's performance on attention tasks across pre-test, intervention, and post-test sessions. Performance during the pre-test phase remained low and variable (scores =1-2), increased substantially during the intervention phase (scores =4-5), and declined during the post-test phase while remaining above baseline levels (scores =2-4).

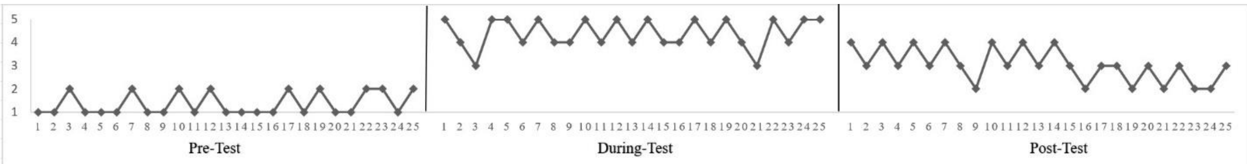

Figure 2

Participant 1's recognition performance across pre-test, during-test, and post-test phases.

Figure 2 presents Participant 1's performance on recognition tasks across pre-test, intervention, and post-test sessions. During the pre-test phase, performance remained low and variable, with scores generally ranging between 1 and 2. Scores increased markedly during the intervention phase (approximately 4-5) and, although reduced during the post-test phase, remained higher than baseline levels, ranging between 2 and 4.

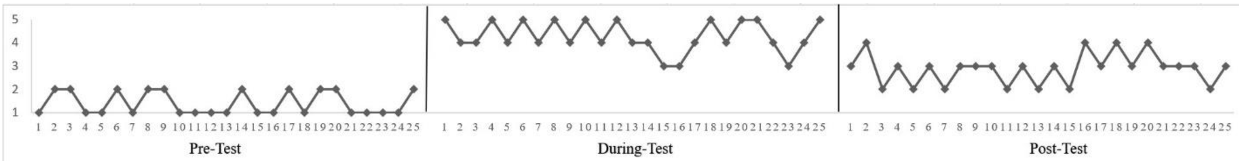

Figure 3
Participant 1's memory performance across pre-test, during-test, and post-test phases.

Figure 3 presents Participant 1's performance on memory tasks across pre-test, intervention, and post-test sessions. During the pre-test phase, performance remained low and variable, with scores generally ranging between 1 and 2. Performance increased substantially during the intervention phase (approximately 4-5) and declined during the post-test phase, while remaining above baseline levels, with scores ranging between 2 and 4.

Visual Analysis of Participant 2 Across Cognitive Domains

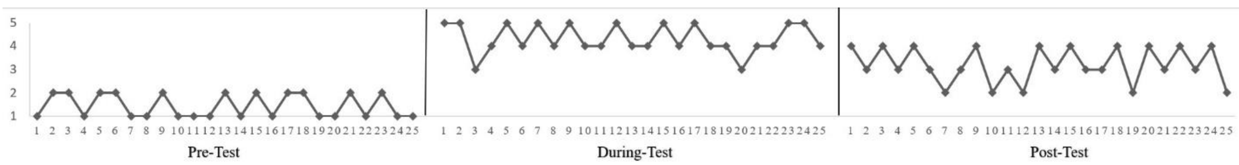

Figure 4
Participant 2's attention performance across pre-test, during-test, and post-test phases.

Figure 4 demonstrates the results of Participant 2 in the area of attention tasks during pre-test, intervention, and post-test sessions. In the pre-test stage, the performance was low and inconsistent with the scores averaging between 1 and 2. The improvement was significantly noted in the intervention period, and all the scores were in a range of 4-5; during the post-test, performance dropped but was not lower than the baseline, the range of the scores was usually 2-4.

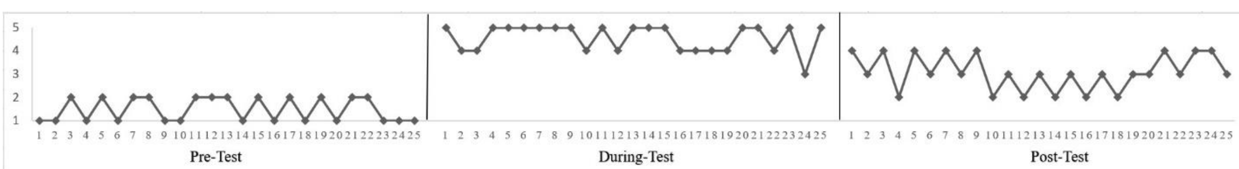

Figure 5
Participant 2's recognition performance across pre-test, during-test, and post-test phases.

Figure 5 presents the recognition task results for Participant 2 across the pre-test, intervention, and post-test. At the pre-test stage, the scores were low and fluctuating (in general, they were in the range of 1-2). Performance was significantly enhanced during the intervention period, and scores remained between 4 and 5. Although the scores decreased during the post-test period, they remained higher than before. At baseline, the performance scores ranged from 2 to 4.

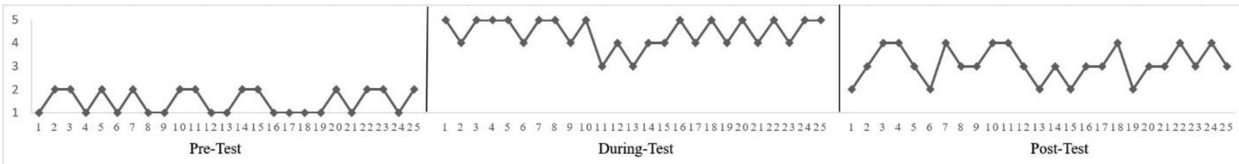

Figure 6

Participant 2's memory performance across pre-test, during-test, and post-test phases.

Figure 6 illustrates Participant 2's performance on memory tasks across sessions. The performance during the pre-test was low and unreliable with the scores being mostly between 1 and 2. There was a significant increase in the performance in the intervention period as the scores were always between 4 and 5 and even though the performance decreased in the post-test period, scores were still higher than the baseline with an average of 2 to 4.

Visual Analysis of Participant 3 Across Cognitive Domains

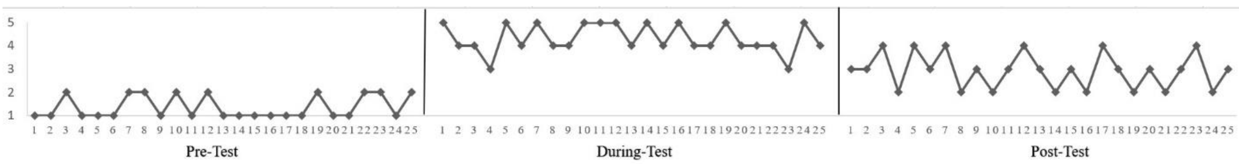

Figure 7

Participant 3's attention performance across pre-test, during-test, and post-test phases.

Figure 7 presents Participant 3's performance on attention tasks across pre-test, intervention, and post-test sessions. At the pre-test stage, performance was poor and erratic, with scores mostly falling between 1 and 2. A significant improvement was observed during the intervention period, with most scores between 4 and 5; however, post-test scores were lower than during the intervention period but still higher than the baseline level, typically between 2 and 4.

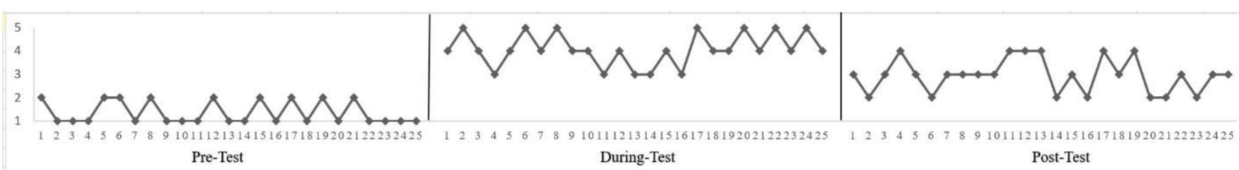

Figure 8

Participant 3's recognition performance across pre-test, during-test, and post-test phases.

Figure 8 presents Participant 3's performance on recognition tasks across pre-test, intervention, and post-test sessions. The scores were low and varied between 1 and 2 during the pre-test phase. Performance increased substantially during the intervention phase, with scores predominantly ranging from 4 to 5, and although scores declined during the post-test phase, they remained higher than baseline levels, generally ranging between 2 and 4.

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Volume 4, Issue 2, 2026

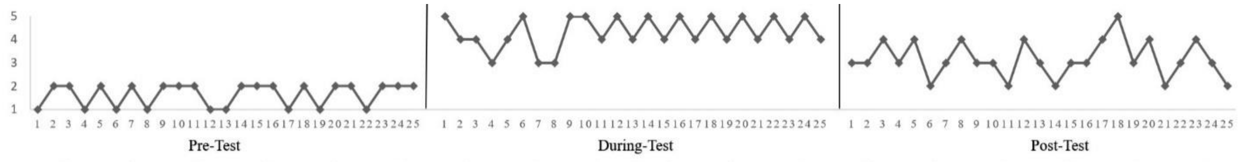

Figure 9
Participant 3's memory performance across pre-test, during-test, and post-test phases.

Figure 9 illustrates Participant 3's performance on memory tasks across pre-test, intervention, and post-test sessions. Performance during the pre-test stage was erratic and low, with scores ranging from 1 to 2. The performance level was significantly better at the intervention stage, and the scores were mostly in the range of 4-5, although the level of score had fallen at the post-test phase, but it was still higher than at the baseline stage, with a range of 2-4.

Visual Analysis of Participant 4 Across Cognitive Domains

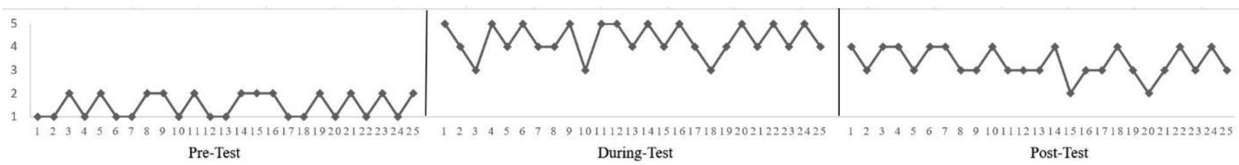

Figure 10
Participant 4's attention performance across pre-test, during-test, and post-test phases.

Figure 10 shows Participant 4's performance on attention tasks across pre-test, intervention, and post-test sessions. Attention scores during the pre-test phase were low and inconsistent, with most falling between 1 and 2. There was a clear and consistent positive change at the time of the intervention, as scores remained between 4 and 5. During the post-test stage, scores declined but remained higher than at baseline, typically ranging from 2 to 4, indicating that attentional gains were partially maintained.

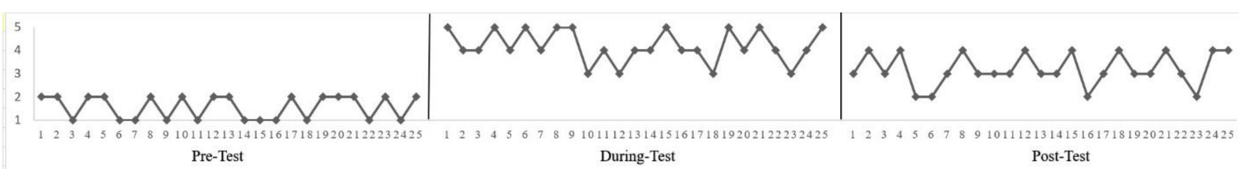

Figure 11
Participant 4's recognition performance across pre-test, during-test, and post-test phases.

Figure 11 shows the session recognition performance of Participant 4. The pre-test scores were also low and inconsistent, with an average of 1-2. There was also a significant improvement in performance during the intervention period, with most scores ranging from 4 to 5, indicating improved stimulus identification. During the post-test, the scores decreased, yet they were still at higher levels of recognition and usually were within 2-4, which means that recognition skills were partly retained.

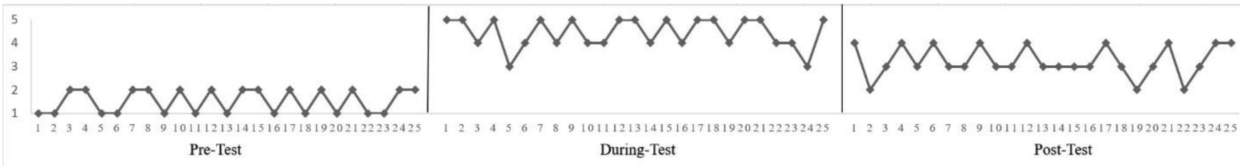

Figure 12
Participant 4's memory performance across pre-test, during-test, and post-test phases.

Figure 12 depicts Participant 4's memory performance during the in-sessions. Memory scores were low and inconsistent throughout the pre-test phase, with most scores between 1 and 2. The intervention showed positive improvement where the average scores of four and five were recorded and this signifies the increased recall. The scores of memory gains were partially retained and were at an average of 2-4 points after the intervention withdrawal and the scores were not at the baseline.

Visual Analysis of Participant 5 Across Cognitive Domains

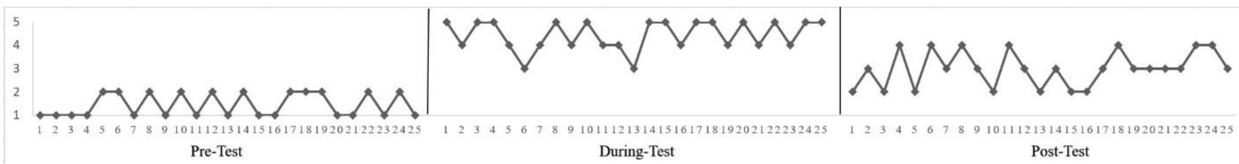

Figure 13
Participant 5's attention performance across pre-test, during-test, and post-test phases.

Participant 5 has been depicted in Fig. 13 as having recognition performance during pre-test, intervention, and post-test. The recognition scores during the pre-test phase were low and inconsistent and they were mostly between 1 and 2. It was noticeable that the improvement in the intervention phase was significant because the scores were always between 4 to 5 indicating better recognition accuracy. Despite a decrease in the performance at the post-test stage, the performance was still better than the baseline scores, which were usually between 2 and 4, which means that there was partial preservation of recognition skills.

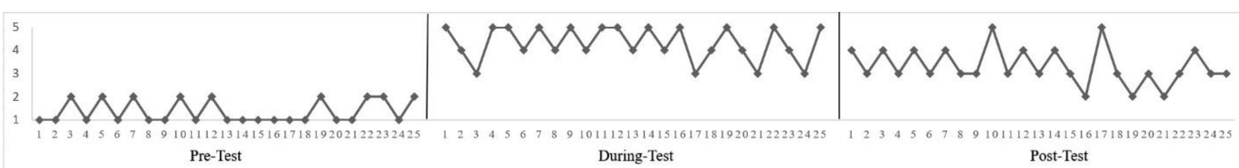

Figure 14
Participant 5's recognition performance across pre-test, during-test, and post-test phases.

Figure 14 shows the recognition performance of the Participant 5 in the pre-test, the intervention, and the post-test session. In the pre-test stage, the performance was low and not stable and the scores were mostly between 1 and 2. The recognition performance increased significantly in the process of intervention where scores generally varied between 4 and 5 implying a high recognition ability. In the post-test phase, scores decreased but remained above baseline, generally ranging between 2 and 4, demonstrating partial retention of recognition gains.

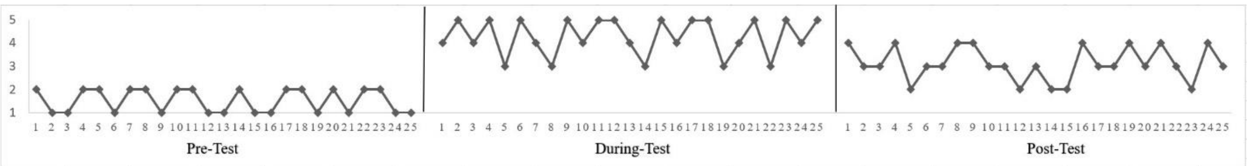

Figure 15
Participant 5's memory performance across pre-test, during-test, and post-test phases.

Figure 15 illustrates Participant 5's memory performance across pre-test, intervention, and post-test sessions. During the pre-test phase, memory scores were low and variable, generally ranging between 1 and 2. During the intervention, there was a noticeable positive change in the responses with the majority of the responses being between 4 and 5 and this showed improved memory performance. During the post-test, scores decreased though they were still higher than the baseline which was 2 to 4 indicating partial retention of memory improvement.

Table 2
Tau-U Effect Size Analysis of Participant 1's Attention Performance

Phase	N	Tau-U	Z-value	p-value	90% CI
Pre-test vs During	625	1.0000	6.0634	< .001	0.729 to 1.000
Pre-test vs Post-test	625	0.9296	5.6365	< .001	0.658 to 1.000
During vs Post-test	625	-0.8256	-5.0059	< .001	-1.000 to -0.554

Participant 1 shows a significant improvement in attention in the intervention stage, as there was a statistically significant difference between pre-tests and the process of intervention (Tau-U = 1.00, p <.001), which means that the response to AI-based attention exercises was immediate and consistent. A significant and large effect was also found in comparison of pre-test and post-test (Tau-U = 0.9296, p <.001) indicating that the gains of attention were highly preserved after the intervention. Nevertheless, a gender difference was observed between the period of intervention and post-test (Tau-U = -0.8256, p <.001). This reduction can be probably explained by the fact that the AI-driven prompts, feedback, and structured support are withdrawn. This had improved, but post-test attention performance was still significantly greater than baseline meaning that there had been a persistent but smaller intervention effect.

Table 3
Tau-U Effect Size Analysis of Participant 1's Recognition Performance

Phase	N	Tau-U	Z-value	p-value	90% CI
Pre-test vs During	625	1.0000	6.0634	< .001	0.729 to 1.000
Pre-test vs Post-test	625	0.9136	5.5395	< .001	0.642 to 1.000
During vs Post-test	625	-0.7936	-4.8119	< .001	-1.000 to -0.522

The scores of Participants 1 indicated that the AI-based intervention had a significant impact on recognition performance, and the difference between the pre-test and the intervention was statistically significant (Tau-U = 1.00, p <.001). Another significant effect was also found between the pre-test and post-test conditions (Tau-U = 0.9136, p < .001) showing that there was a significant retention of benefits in recognition following the intervention. Intervention to post-test recognition performance however suffered a huge hit compared to the time it was during the intervention (Tau-U = -0.7936, p < .001). This reduction can probably be linked to the withdrawing AI-assisted prompts, feedback, and guided practice. Although this was lower, the post-test performance was still significantly higher than the baseline which indicates that the intervention sustained but with a smaller impact on recognition skills.

Table 4
Tau-U Effect Size Analysis of Participant 1's Memory Performance

Phase	N	Tau-U	Z-value	p-value	90% CI
Pre-test vs During	625	1.0000	6.0634	< .001	0.729 to 1.000
Pre-test vs Post-test	625	0.8880	5.3843	< .001	0.617 to 1.000
During vs Post-test	625	-0.8176	-4.9574	< .001	-1.000 to -0.546

Participant 1 results show that the AI-based intervention had a strong effect on memory performance, and the result from pre-test to intervention changed significantly (Tau-U = 1.00, p < .001), which was an immediate and constant response to AI-assisted memory tasks. The pre-test and post-test (Tau-U = 0.888, p <.001) also showed a large and significant effect indicating that a significant portion of the memory gains were maintained after intervention. Nevertheless, during intervention to post-test there was a considerable decrease (Tau-U = -0.8176, p <.001). It is possible that this decrease is due to the removal of AI-based suggestions, feedback, and structured instructions. Although this reduced, the memory performance after the post test was higher than the beginning of the test, which shows that the effect of the intervention was lasting although less pronounced.

Table 5
Tau-U Effect Size Analysis of Participant 2's Attention Performance

Phase	N	Tau-U	Z-value	p-value	90% CI
Pre-test vs During	625	1.0000	6.0634	< .001	0.729 to 1.000
Pre-test vs Post-test	625	0.9120	5.5298	< .001	0.641 to 1.000
During vs Post-test	625	-0.6960	-4.2201	< .001	-0.967 to -0.425

The outcomes of Participant 2 revealed that there was a significant impact of the AI-based intervention on the attention performance, and the statistically significant improvement between the pre-test performance and the performance at the time of intervention (Tau-U = 1.00, p < .001). Another significant and large effect was also noted between pre-test and post-test conditions (tau-U = 0.912 p =0.001) that the majority of attention gains were retained after the intervention. Nonetheless, considerable decrease was observed between intervention and post-test (Tau-U = -0.696, p <.001). The reduction is most probably connected with the withdrawal of AI-based prompts, feedback and structured information. Although this was less impressive than the baseline, the post-test performance was still better than the baseline indicating that there was a long-term but less pronounced impact of the intervention on attention skills.

Table 6
Tau-U Effect Size Analysis of Participant 2's Recognition Performance

Phase	N	Tau-U	Z-value	p-value	90% CI
Pre-test vs During	625	1.0000	6.0634	< .001	0.729 to 1.000
Pre-test vs Post-test	625	0.8848	5.3649	< .001	0.613 to 1.000
During vs Post-test	625	-0.8416	-5.1029	< .001	-1.000 to -0.570

The findings of Participant 2 indicate that the AI-based intervention has a considerable effect on the recognition performance and that the difference between the pre-test performance and the one at the moment of the intervention is statistically significant (Tau-U = 1.00, p <.001). Pre-test and post-test (Tau-U 0.8848, p <. 001) also exhibited significant and great difference, which means that the gains of recognition retained after the intervention were significant. However, the difference between the post-test and the time of intervention was significantly reduced (Tau-U = -0.8416, p <.001). This reduction should likely be associated with the withdrawal of AI based prompts, feedback and guided practice. Even in this case, this improvement was less, but post-test recognition performance was improved than at baseline, although at a later time.

Table 7
Tau-U Effect Size Analysis of Participant 2's Memory Performance

Phase	N	Tau-U	Z-value	p-value	90% CI
Pre-test vs During	625	1.0000	6.0634	< .001	0.729 to 1.000
Pre-test vs Post-test	625	0.9040	5.4813	< .001	0.633 to 1.000
During vs Post-test	625	-0.7824	-4.7440	< .001	-1.000 to -0.511

Participant 2 results revealed that AI-based intervention had a significant impact on memory performance, and the difference between pre-test and within the intervention were statistically significant (Tau-U = 1.00, p <.001). There was also a significant and large effect between pre-test and post-test phases (Tau-U = 0.904, p <.001), which showed that the majority of memory gains were retained upon the intervention. Nevertheless, there was a significant decrease in performance of memory between intervention and post-test (Tau-U = -0.7824, p =.001). This loss can be explained by the removal of AI-guided practice, feedback and prompts. Although this decrease was achieved, the level of performance in the end of the test was still higher than the baseline, which indicates that the intervention had a lasting, albeit smaller, impact on memory abilities.

Table 8
Tau-U Effect Size Analysis of Participant 3's Attention Performance

Phase	N	Tau-U	Z-value	p-value	90% CI
Pre-test vs During	625	1.0000	6.0634	< .001	0.729 to 1.000
Pre-test vs Post-test	625	0.8848	5.3649	< .001	0.613 to 1.000
During vs Post-test	625	-0.8016	-4.8604	< .001	-1.000 to -0.530

According to the results of Participant 2, the AI-based intervention has such a strong impact on the performance in terms of attention that the effect of the interventions on the pre-test performance and the performance throughout the intervention may be considered statistically significant (Tau-U = 1.00, p < .001). There was also a significant effect between pre-test and post-test phases with a large effect (Tau-U = 0.8848, p <.001); it indicated that the effects of gaining attention were mainly retained after the intervention. Nevertheless, that there was a considerable decrease between during intervention and post-test (Tau-U = -0.8016, p < .001). This decrease can probably be explained by the dissociation of AI-based prompts, feedback, and formatted support. Although this decrease has occurred, the post-test attention performance was still higher than baseline which means that there was a persistent but smaller effect of the intervention.

Table 9
Tau-U Effect Size Analysis of Participant 3's Recognition Performance

Phase	N	Tau-U	Z-value	p-value	90% CI
Pre-test vs During	625	1.0000	6.0634	< .001	0.729 to 1.000
Pre-test vs Post-test	625	0.8992	5.4522	< .001	0.628 to 1.000
During vs Post-test	625	-0.6832	-4.1425	< .001	-0.955 to -0.412

Participant 3 outcomes showed that the AI-based intervention had a significant effect on recognition performance with a statistically significant increase in the performance of the pre-test and during the intervention (Tau-U = 1.00, p <.001). There was also a large and significant effect between pre-test and post-test phases (Tau-U = 0.8992, p <.001), which revealed the substantial retention of the gains of recognition after the intervention. But the recognition performance was found to be much lower at the post-test as compared to the intervention (Tau-U = -0.6832, p < .001). This reduction could be explained by the removal of AI-based prompts, feedback, and guided practice. Although all this decreased, the post-test performance was still higher than baseline, which indicates the effect of the intervention had sustained but minimized effect on recognition skills.

Table 10
Tau-U Effect Size Analysis of Participant 3's Memory Performance

Phase	N	Tau-U	Z-value	p-value	90% CI
Pre-test vs During	625	1.0000	6.0634	< .001	0.729 to 1.000
Pre-test vs Post-test	625	0.8720	5.2873	< .001	0.601 to 1.000
During vs Post-test	625	-0.6896	-4.1813	< .001	-0.961 to -0.418

The results of Participant 3 in the study show a large impact of the AI-based intervention on memory performance, with the statistically significant improvement since pre-test to the time of the intervention (Tau-U = 1.00, p <.001). There was also a large and significant effect between the pre-test and post-test phases (Tau-U = 0.872, p =.001) indicating that a considerable number of gains on memory was maintained after the intervention. Nevertheless, the performance of memory decreased dramatically between intervention and post-test (Tau-U = -0.6896, p <.001). This reduction can be explained by the fact that the AI-based prompts, feedback, and guided practice are withdrawn. Although this was less than at baseline, post-test performance was still higher than at the baseline, which showed that the intervention had a persistent effect, albeit smaller, in memory skills.

Table 11
Tau-U Effect Size Analysis of Participant 4's Attention Performance

Phase	N	Tau-U	Z-value	p-value	90% CI
Pre-test vs During	625	1.0000	6.0634	< .001	0.729 to 1.000
Pre-test vs Post-test	625	0.9616	5.8306	< .001	0.690 to 1.000
During vs Post-test	625	-0.6656	-4.0358	.0001	-0.937 to -0.394

Results of Participant 4 showed that the AI-based intervention had a significant effect on attention performance, and the difference between pre-test and at the time of intervention was statistically significant (Tau-U = 1.00, p <.001). Significant and a large difference was also found in pre-test and post-test (Tau -U= 0.9616, p <.001) meaning that much of the gains in attention were retained within the intervention. Nevertheless, the performance in attention deteriorated enormously between intervention and post-test (Tau -U = -0.6656, p =.0001). This is most probably related to the removal of AI-based prompts, feedback, and guided instructions. In spite of this decrease, the post-test performance in attention was still greater as compared to baseline, which implies that the intervention had a long-lasting but smaller implication on attention abilities.

Table 12
Tau-U Effect Size Analysis of Participant 4's Recognition Performance

Phase	N	Tau-U	Z-value	p-value	90% CI
Pre-test vs During	625	1.0000	6.0634	< .001	0.729 to 1.000
Pre-test vs Post-test	625	0.9104	5.5201	< .001	0.639 to 1.000
During vs Post-test	625	-0.6352	-3.8515	.0001	-0.907 to -0.364

The results of Participant 4 reveal that the AI-based intervention highly influenced the recognition performance, and the difference between levels before and during the intervention was statistically significant (Tau-U = 1.00, p <.001). The significant and large effect was also found between pre-test and post-test stages (Tau-U = 0.9104, p <.001), which indicated a considerable retention of recognition gains following the intervention. Nevertheless, the recognition performance changed considerably between the time of intervention and post-test (Tau-U = -0.6352, p =.0001). This reduction can be explained by the removal of the AI-based prompts and feedback as well as guided practice. Although this decrease was observed, the recognition performance was still higher after the test, compared to the baseline, and this showed that the intervention had a lasting, although less, effect on recognition abilities.

Table 13
Tau-U Effect Size Analysis of Participant 4's Memory Performance

Phase	N	Tau-U	Z-value	p-value	90% CI
Pre-test vs During	625	1.0000	6.0634	< .001	0.729 to 1.000
Pre-test vs Post-test	625	0.9376	5.6850	< .001	0.666 to 1.000
During vs Post-test	625	-0.7568	-4.5888	< .001	-1.000 to -0.485

The findings of the Participant 4 revealed that the AI-based intervention had a strong impact on the memory performance, and the pre-test and intervention performance were statistically different (Tau-U = 1.00, p < .001). One of the other large and significant effects was also noted between pre-test and post-test phases (Tau-U = 0.9376, p <.001), meaning that the gains in memory were also mostly preserved after the intervention. Nevertheless, the post-test memory performance deteriorated dramatically compared to the results obtained in the intervention (Tau-U = -0.7568, p <.001). Such a decrease can probably be explained by the fact that AI-based prompts, feedback, and guided practice were withdrawn. Although this decrease was seen, post-test memory performance was still higher than baseline indicating that the effect of the intervention on memory skills is sustained and yet diminished.

Table 14
Tau-U Effect Size Analysis of Participant 5's Attention Performance

Phase	N	Tau-U	Z-value	p-value	90% CI
Pre-test vs During	625	1.0000	6.0634	< .001	0.729 to 1.000
Pre-test vs Post-test	625	0.8768	5.3164	< .001	0.605 to 1.000
During vs Post-test	625	-0.8080	-4.8992	< .001	-1.000 to -0.537

The outcomes of Participant 5 showed that the AI-based intervention had a significant impact on the attention performance, and the difference between the pre-test outcomes and the intervention was statistically significant (Tau-U = 1.00, p <.001). It was also found that there was a large and significant difference in pre-test to post-test (Tau-U = 0.8768, p < .001) indicating that the gains in attention were long-lasting following the intervention. Nevertheless, there was a great loss between during intervention and post-test (Tau-U = -0.808, p < .001). This drop can probably be explained by the removal of AI-based prompts, feedback, and guide structural support. In spite of this loss, performance on post-test attention was higher than baseline, which showed a sustained but lesser effect of the intervention.

Table 15
Tau-U Effect Size Analysis of Participant 5's Recognition Performance

Phase	N	Tau-U	Z-value	p-value	90% CI
Pre-test vs During	625	1.0000	6.0634	< .001	0.729 to 1.000
Pre-test vs Post-test	625	0.9568	5.8015	< .001	0.685 to 1.000
During vs Post-test	625	-0.6048	-3.6671	.0002	-0.876 to -0.333

The results of the Participant 5 showed that the AI-based intervention significantly influenced the recognition performance, and the performance significantly improved in the pre-test to the intervention (Tau-U = 1.00, p < .001). The same significant and large effect was also noted across the pre-test and post-test (Tau-U = 0.9568, p <.001) which indicated that recognition gains had a high level of retention at the end of the intervention. Nevertheless, recognition was worse on post-test than in the intervention period (Tau-U = -0.6048, p =.0002). This reduction can be explained by the retraction of AI-prompts, feedback, and guided practice. Although this was lower, post-test recognition performance was greater than baseline indicating a longer-lasting, albeit smaller impact of the intervention.

Table 16
Tau-U Effect Size Analysis of Participant 5's Memory Performance

Phase	N	Tau-U	Z-value	p-value	90% CI
Pre-test vs During	625	1.0000	6.0634	< .001	0.729 to 1.000
Pre-test vs Post-test	625	0.8960	5.4328	< .001	0.625 to 1.000
During vs Post-test	625	-0.6736	-4.0843	< .001	-0.945 to -0.402

The findings of Participant 5 indicated that there was a significant impact of the AI-based intervention on memory performance, with the statistically significant difference in memory performance between pre-test and during the intervention (Tau-U = 1.00, p <.001). The effect was also found to be large and significant between pre-test and post-test phases (Tau-U = 0.896, p < .001) which means that the majority of memory gains were maintained after the intervention. Nevertheless, the performance on memory improved considerably between intervention and post-test (Tau-U = -0.6736, p <.001). This reduction could be explained by the removal of prompt AI, guidance, and feedback. Although this reduction was made, the post-test memory performance was still better than the baseline indicating that the intervention had a long-lasting but lesser effect on the memory skills.

Findings

The major findings for five participants are presented below.

Participant 1

Participant 1 demonstrated a very impressive outcome during the intervention period. The immediate and strong gains were in the three areas

INTERNATIONAL JOURNAL OF SOCIAL SCIENCES BULLETIN
ISSN: (E) 3007-1917 (P) 3007-1909
Volume 4, Issue 2, 2026

of cognitive skills. Attention performance demonstrated a perfect intervention effect from the pre-test to the intervention (Tau-U = 1.00, $p < .001$), but there was a substantial retained effect at the post-test (Tau-U = 0.9296, $p < .001$). This was similarly the case with recognition (pre-during Tau-U = 1.00; pre-post Tau-U = 0.9136, $p < .001$) and memory (pre-during Tau-U = 1.00; pre-post Tau-U = 0.8880, $p < .001$). Although performance was lower than before the AI support was withdrawn (intervention-post Tau: U between -0.79 and -0.83), post-test scores in all domains were significantly higher than at baseline. These results demonstrate effective learning with partial retention and point out the value of AI-based scaffolding in maintaining performance gains.

Participant 2

Participant 2 was highly responsive to the AI-based intervention, and the pre-test change for attention, recognition, and memory was perfect (Tau-U = 1.00, $p < .001$). There were strong retention effects at post-test for attention (Tau-U = 0.9120), recognition (Tau-U = 0.8848), and memory (Tau-U = 0.9040), all statistically significant ($p < .001$). Intervention withdrawal resulted in poor performance (Tau-U scores ranging from -0.70 to -0.84), but post-test scores were significantly higher than baseline. This trend suggests effective learning that may continue to benefit, yet it also indicates some reliance on AI-generated prompts and feedback.

Participant 3

Participant 3 showed significant improvement in intervention, especially in recognition and memory with Tau-U pre-test to intervention values of 1.00 ($p < .001$) in all domains. Retention effects of attention (Tau-U = 0.8848), recognition (Tau-U = 0.8992), and memory (Tau-U = 0.8720) were large post-test retention effects. Nonetheless, there was a significant decrease after AI withdrawal (intervention post Tau-U values ranged between -0.68 to -0.80). Although there is this reduced performance, the post-test performance was higher than the baseline, meaning that there was significant cognitive learning, albeit with lower independent functioning without structured AI support.

Participant 4

Participant 4 depicts substantial and consistent improvements in attention, recognition, and memory throughout the intervention (Tau-U = 1.00, $p < .001$). Post-test retention was very strong, particularly for attention (Tau-U = 0.9616) and memory (Tau-U = 0.9376), and recognition showed a strong retained effect (Tau-U = 0.9104). Despite the deterioration in performance following intervention withdrawal (Tau-U = -0.64 to -0.76), post-test scores remained significantly higher than baseline. This trend suggests that cognitive abilities are highly internalized and rely less on constant AI scaffolding than those of other subjects.

Participant 5

Participant 5 was highly and steadily improved throughout the intervention period in all domains, with tau-u pre-test to intervention Tau-U equal to 1.00 ($p < .001$). Attention (Tau-U = 0.8768), recognition (Tau-U = 0.9568) and memory (Tau-U = 0.8960) had large post-test retention effects. Despite the decrease of performance caused by intervention withdrawal (Tau-U values ranging between -0.60 and -0.81), the level of performance at the end of the post-test was still higher than at the start of the performance in all areas. These results show significant learning, and improvements had been partially sustained over time, even in the absence of continued AI support.

Conclusion

The current research investigated the efficacy of AI-based applications in enhancing attention, recognition, and memory in children with intellectual disabilities in a single-subject A-B-A design of study. The findings indicated that there were both considerable and meaningful improvements in all the cognitive areas in all the subjects during the intervention duration, indicating that AI-assisted education could be useful in facilitating cognitive performance in the context of instructional organization. Despite the drop in the performance after the withdrawal of the intervention, by the conclusion of the post-test, the scores were high compared to the baseline in most of the people, which shows retention of at least part of gains. According to the trend, AI-based cognitive scaffolding (prompts, feedback, and guided practice) has a significant role in enhancing the level of learning and performance. Overall, the study provides strong grounds to believe that AI-based devices can be effective in special education and help develop thinking skills in children with intellectual disabilities.

Discussion

The results of the current research align with the existing literature, which suggests that technology-enhanced instructional interventions may be effective in promoting attention, recognition, and memory in children with intellectual disabilities. These significant changes that were made in the course of the intervention phase are in line with previous research findings, which show that structured digital settings, especially the ones that utilize instant feedback and practice, facilitate cognitive involvement and skill learning in this group of people (Schalock et al., 2010; Van der Molen et al., 2010; Lancioni et al., 2019; and Torra Moreno et al., 2021). This deterioration in performance after the removal of AI-based support is consistent with prior intervention research, which has reported lower performance in the absence of external instructional scaffolding (Bouck and Flanagan, 2009; Ha et al., 2021). The post-test performance, even at baseline levels, indicates that the intervention did not produce short-term performance effects but did yield meaningful learning, consistent with previous studies of technology-based cognitive training (Dede, 2014; Hopcan et al., 2023). In general, their findings can further existing research by providing intervention-based evidence based on direct cognitive measurement and single-subject analysis, thereby justifying the instructional importance of AI-based applications in special education settings.

Recommendations

1. Special education educators should incorporate AI-based applications as auxiliary instructional tools to support attention, recognition, and memory in children with intellectual disabilities.
2. School administrators need to ensure that they have access to AI-based tools and can use them effectively in the classroom.
3. Policymakers in education must integrate AI-assisted instruction into special education systems and allocate funds for infrastructure and teacher training.

Implications

This study has several practical implications for special education practice. First, AI-based applications can be used effectively in teaching programs to promote attention, recognition, and memory in children with intellectual disabilities, particularly when supported by systematic instruction, prompts, and feedback. Teachers and therapists can use these applications as an additional tool to support classroom instruction and to provide personalized practices aligned with a specific learner's pace and needs. Second, the level of support should be adjusted by frequently monitoring each student's progress to ensure it aligns with their individual responsiveness. Finally, school administrators and policymakers should consider incorporating AI-based applications into the special education curriculum and professional development programs. The efficacy of AI could be improved by training teachers in how to effectively use technology in special education, contributing to the prevention of its misuse, and making it clear that its advantages in teaching are evident.

Limitations

While the results were encouraging, it's important to acknowledge a few limitations. First of all, the research is based on the A-B-A design, and a small sample size restricts its scope toward the overall population of children with intellectual disabilities. More extensive and diverse samples should be used in studies to promote the external validity, although single-case studies are well-adapted to intervention-based research. The research was on three cognitive areas, including attention, recognition, and memory, and other critical areas, including executive functioning, language, and adaptive behavior, were not investigated.

Future Research

The future research studies should also take into consideration the use of bigger sample sizes and hybrid designs, which integrate the single-subject methodology and a group-based technique to enhance generalizability. Longitudinal studies are necessary when it comes to determining the sustainability and transferability of cognitive gains after the intervention. In addition, further studies ought to investigate ways of altering AI systems to enhance software performance. A more in-depth analysis of the positive and negative impacts of certain AI functionalities, the potential of the applications of these interventions in special education to the larger spheres of thinking and functioning would enhance our comprehension of how AI can be utilized in special education.

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