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The impact of metacognitive strategies on braille reading accuracy: A Single-Subject A-B-A study with students with visual impairment

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Abstract

Braille literacy is essential for the academic development and independence of students with visual impairments. However, previous studies have primarily focused on reading comprehension or assistive technology, with limited attention to the accuracy of Braille reading as a critical foundation for reading proficiency. This study aims to examine the effectiveness of metacognitive reading strategies in improving Braille reading accuracy among blind students by employing a single-subject experimental A-B-A design. Three blind students from a special junior high school in Surabaya, Indonesia, participated in this study. The intervention consisted of structured metacognitive strategies including planning, monitoring, and evaluating during Braille reading sessions. Accuracy levels were measured using the Informal Reading Inventory (IRI) across three phases: baseline (A1), intervention (B), and withdrawal (A2). Data were analyzed through visual inspection to detect performance trends and level changes across phases. In addition to the visual analysis, this study also calculated the effect size using the Percentage of Non-Overlapping Data (PND) to measure the magnitude of the intervention's impact. Findings revealed a substantial increase in Braille reading accuracy during the intervention phase (Level: Independent) compared to both baseline phases (Level: Instructional). A reversal effect occurred when the intervention was withdrawn, indicating a causal relationship between metacognitive strategy implementation and improved reading accuracy. The PND calculation showed a value of 100% for all three participants, indicating that all intervention scores exceeded the highest baseline score, thus categorizing the intervention as highly effective. The study demonstrates that metacognitive reading strategies significantly enhance Braille reading accuracy, fostering independent and reflective reading habits among blind students. These findings highlight the potential for integrating metacognitive approaches into inclusive literacy instruction, addressing a critical gap in existing research.

Keywords: Metacognitive reading strategy, Braille reading accuracy, Single subject research, Students with visual impairment

Introduction

Reading ability is a very important fundamental skill in the cognitive and academic development of every student, including students with visual impairment. For students with visual impairment, the reading process is carried out through Braille, which requires tactile skills, finger sensitivity, and effective information processing strategies. However, various studies indicate that students with visual impairment tend to experience difficulties in achieving reading accuracy and text comprehension equivalent to their sighted peers. (Castellano, 2010; Wanja et al., 2021). This barrier not only affects academic achievement but also hinders their independence and participation in social life (R. Ryles, 1996; R. N. Ryles, 1997).

Reading accuracy is the main foundation in developing the reading skills of students with visual impairment. Without adequate accuracy in reading Braille, students will have difficulty accessing information fully. Therefore, the ability to recognize and accurately articulate Braille symbols becomes the primary requirement for literacy success among students with visual impairment (Channa et al., 2015; Gardner, 1987; Savaiano & Hatton, 2013). Students with visual impairment who rely on Braille not only need to accurately recognize Braille symbols but also connect and interpret information from the text to build a broader understanding of the content of their readings (Argyropoulos & Papadimitriou, 2015; Birns, 1976; Chen et al., 2023; Wanja et al., 2021). Without adequate comprehension, students with visual impairment face a major challenge in accessing essential knowledge, which can affect their learning outcomes across various subjects. (Chen et al., 2023; R. Ryles, 1996; R. N. Ryles, 1997).

In reading Braille, reading accuracy refers to the ability to read correctly without making errors in

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recognizing Braille symbols. (Chen et al., 2023). Empirical research demonstrates that specific Braille reading errors, such as word repetitions, omissions, and phonological inaccuracies, frequently serve as significant obstacles to achieving accurate textual comprehension (Chen et al., 2023). Several studies indicate that Braille readers read with a slightly lower level of accuracy compared to print readers (Argyropoulos & Papadimitriou, 2015; Veispak, Boets, & Ghesquiere, 2012; Veispak, Boets, Männamaa, et al., 2012; Wanja et al., 2021; Jam et al., 2025). Dodd & Conn (2000) estimate that the Braille readers participating in their study lagged approximately 10 months in accuracy levels compared to their sighted peers. Therefore, Braille reading accuracy is the foundation for better comprehension, which in turn opens up opportunities for better cognitive and academic development for students with visual impairment.

The implementation of metacognitive strategies represents a promising approach for enhancing Braille reading accuracy among students with visual impairments. These metacognitive reading strategies, which underscore the self-awareness and regulatory control of cognitive processes during text engagement, are posited to significantly improve the overall reading competency of this student population. Specifically, for Braille readers, metacognitive training is expected to foster greater consciousness of their reading execution, enable proactive error detection during decoding, and facilitate the self-regulation of reading speed and comprehension (Al-Hilawani, 2006; Argyropoulos et al., 2012; Athira & Chacko, 2020; Borca, 2015; Madhavi K & Venukapalli, 2017). Prior research has demonstrated that metacognitive strategies, including comprehension monitoring and the strategic planning of reading approaches, are instrumental in enhancing both reading accuracy and textual understanding among sighted readers (Channa et al., 2015; Jacobs & Paris, 1987; Mokhtari, 2016; Mokhtari & Reichard, 2002). Furthermore, prior studies consistently report that readers who effectively develop metacognitive control during the reading process typically exhibit a significantly higher degree of reading accuracy (Jacobs & Paris, 1987).

Although the efficacy of metacognitive strategies is well-established for sighted readers, their application remains underexplored among students with visual impairments, particularly within the specific context of Braille literacy. Moreover, research systematically quantifying individual change in Braille reading accuracy following metacognitive instruction, particularly through the rigorous A-B-A single-subject experimental design, is notably scarce. The A-B-A design is crucial as it provides a structured methodology for the precise measurement of behavioral modification by establishing a baseline phase (A), implementing the intervention (B), and subsequently conducting a return-to-baseline/withdrawal evaluation (A) (Cakiroglu, 2012; Kazdin, 1982; Riley-Tillman et al., 2009). This methodological approach facilitates the observation of discernible changes in the Braille reading accuracy of students with visual impairments, comparing performance across the phases preceding and following the implementation of metacognitive strategies.

The specific objectives of the present study are twofold: (1) to systematically describe the Braille reading accuracy levels demonstrated by students with visual impairments across the baseline and post-intervention phases of the metacognitive strategy implementation, (2) to evaluate the efficacy of the metacognitive strategies in enhancing Braille reading accuracy among the target population. Correspondingly, the study addresses the following research questions: (1) What are the observed Braille reading accuracy levels among students with visual impairments before and after the metacognitive strategy intervention? (2) to what extent does the implementation of metacognitive strategies effectively increase the students' level of reading accuracy?

Focusing specifically on students with visual impairments at the junior high school level, this study is anticipated to offer a significant contribution to the development of more adaptive, metacognitive-awareness-based reading instruction models. Furthermore, the findings are expected to substantially expand the existing understanding of the critical role of implementing metacognitive strategies within the educational framework for this student population.

Theoretical framework

Metacognitive reading strategies

Metacognition is conceptually defined as an individual's self-awareness and regulatory command over their intrinsic cognitive processes (Flavell, 1979; Paris & Winogard, 1990). Within the reading context, metacognitive strategies encompass three primary processes: pre-reading planning, online comprehension monitoring during text engagement, and post-reading outcome evaluation (Baker & Brown, 1980; Gardner, 1987; Mokhtari, 2016; Mokhtari & Reichard, 2002).

The inherent challenges of visual information acquisition during Braille decoding necessitate that students with visual impairments rely extensively on sophisticated cognitive and metacognitive processing for successful reading (Athira & Chacko, 2020; Coppins & Barlow-Brown, 2006; Millar, 2003; Wanja et al., 2021). For students with visual impairments, metacognitive strategies play a crucial role in enhancing attentiveness to fine Braille detail, proactively mitigating symbol recognition errors, and fostering self-reflection on Braille reading miscues (Al-Hilawani, 2006; Argyropoulos et al., 2012). Although metacognitive strategy research has consistently demonstrated positive outcomes for academic performance, particularly within the reading domain among sighted students (Arianto et al., 2023; Becirovic et al., 2017; Channa et al., 2015; Dignath & Büttner, 2008; Muhid et al., 2020; Shih & Huang, 2018; Thongwichit & Buripakdi, 2021), empirical studies specifically investigating its application to students with visual impairments remain notably scarce. By cultivating this metacognitive awareness, students with visual impairments are empowered to self-correct frequent Braille reading errors, including word repetitions, symbol substitutions, and lexical omissions (Chen et al., 2023).

Characteristics and challenges in braille reading accuracy

Braille literacy constitutes a complex neurocognitive process necessitating the ability to tactilely discriminate patterns of embossed dots and subsequently transcribe these patterns into coherent, meaningful linguistic units (Daneman, 1988; Foulke, 1982; Herzberg et al., 2017). In contrast to visual literacy, Braille decoding is fundamentally dependent on highly regulated digital movement and the effective utilization of haptic-spatial memory (Chen et al., 2023; Millar, 2003; Stanfa & Johnson, 2015). Reading fluency (i.e., speed and accuracy) is consistently reported as lower among students with visual impairments compared to their sighted student, this performance deficit is partially attributable to the inherent complexity of the Braille code and the intensive, continuous manual coordination required for successful decoding (Veispak, Boets, & Ghesquiere, 2012; Veispak, Boets, Männamaa, et al., 2012).

Reading accuracy is defined as the individual's proficiency level in decoding written text by correctly articulating words as they appear in the source material (Chen et al., 2023). The degree of Braille reading accuracy is critically dependent upon the precise identification of the dot configurations contained within each Braille cell. (Dodd & Conn, 2000). For students with visual impairments, Braille reading accuracy is typically quantified via structured error analysis conducted during the process of oral Braille text reading (Chen et al., 2023; Sun et al., 2022). Several studies have successfully developed an analytical framework for Braille reading errors utilizing six primary indicators: mispronunciation, omission, substitution, insertion, repetition, and self-correction. (Chen et al., 2023; Hudson et al., 2005, 2005; Petscher & Kim, 2011). Empirical evidence demonstrates that specific reading miscues—including mispronunciation, omission, substitution, insertion, repetition, and self-correction—significantly impair the attainment of accurate textual comprehension (Chen et al., 2023).

Research gaps and the rationale for the study

The prevailing research on students with visual impairments predominantly emphasizes reading comprehension or the utilization of assistive technology, while the intrinsic component of Braille reading accuracy has rarely constituted a primary focus, particularly when examined through metacognitive strategy-based interventions. Accordingly, this study addresses this empirical deficit by evaluating the efficacy of metacognitive strategies in enhancing Braille reading accuracy. This research fills the gap by integrating metacognitive

strategies into Braille instruction and assessing their influence on Braille reading accuracy via a single-subject A-B-A design. The expected contribution of this investigation is twofold: it will strengthen the theoretical foundation concerning metacognitive strategies in inclusive education and provide practical implications for the development of adaptive reading instruction for this population. Therefore, this study aims to address this empirical gap by evaluating the efficacy of integrating metacognitive strategies into Braille instruction to enhance reading accuracy. Specifically, the study employs a rigorous single-subject A-B-A design to (1) describe the observed Braille reading accuracy levels among students with visual impairments across baseline and post-intervention phases, and (2) quantify the extent to which the metacognitive intervention effectively increases this accuracy level.

Material and Method

Design

The methodological framework for this study utilizes a Multiple Baseline Across Participants Design, a robust form of single-subject research. This design incorporates three distinct phases: Baseline (A), Intervention (B), and Withdrawal/Return-to-Baseline (A). The Multiple Baseline approach was selected primarily for its internal validity strengths: (1) to establish a clear functional relationship by demonstrating that behavioral change is specifically attributable to the intervention and not to extraneous variables; and (2) to affirm the stability of the target behavior during the baseline phase, despite systematic variations in its duration across participants, which is achieved through frequent measurement. By staggering the onset of the intervention for each participant, the Multiple Baseline design effectively allows the researcher to rule out alternative explanations for observed changes during the treatment phase (Morgan & Morgan, 2008)

Setting

The study was implemented within a Special Junior High School dedicated to students with visual impairments, located in Surabaya, Indonesia. The participants comprised 8th-grade students from this institution. The intervention phase was administered twice weekly for a duration of 60 minutes per session, immediately following regular school hours. To ensure optimal conditions, each participant was individually placed in an unoccupied classroom within the school building. This controlled setting was purposefully selected to promote a focused and secure learning environment while effectively minimizing potential auditory and environmental distractions for the students with visual impairments.

Prosedure

The A-B-A design is instrumental in systematically tracking individual changes in competency by allowing researchers to closely monitor student performance across its three distinct phases.

a) The Baseline phase (A1) was dedicated to collecting pre-intervention data to establish the initial performance level of the students with visual impairments regarding their Braille reading accuracy in the absence of treatment. During this period, the three participants were required to read a standardized text without the benefit of the metacognitive strategies to be subsequently taught. The researcher systematically documented the participants' reading accuracy scores (or the frequency of reading errors/miscues) across multiple sessions until the data demonstrated sufficient stability or a clear trend.
b) The Intervention phase (B) involved systematically teaching and instructing the participants in the use of metacognitive reading strategies (e.g., comprehension monitoring, error correction, and pre-reading strategy selection). Braille reading accuracy continued to be the primary dependent measure throughout this phase. The metacognitive strategies were delivered within structured instructional sessions utilizing direct, guided instruction. The training focused on the following key components:

1.Planning: Assisting students in formulating their approach to the text, including setting a specific reading focus and predicting word meanings or overall textual content.

2.Monitoring: Encouraging participants to

engage in online comprehension monitoring during reading and to proactively self-correct reading miscues as they occur.

3.Evaluation: Promoting the post-reading evaluation of their textual understanding to ensure comprehensive grasp of the reading material.

c) The Baseline phase (A2) is characterized by the discontinuation of the intervention. Participants revert to the original baseline condition, meaning they are neither instructed nor prompted to employ the metacognitive strategies. The primary purpose of this phase is to assess the maintenance and generalization effects of the intervention; specifically, the researcher evaluates whether the improvements in reading accuracy achieved during Phase B are sustained or if the performance reverts to the original baseline levels. Continuous measurement of Braille reading accuracy is conducted throughout this phase.

The entire study was implemented over a duration of 15 consecutive weeks. The specific allocation of sessions across the Baseline (A1), Intervention (B), and Withdrawal (A2) phases for each participant is detailed below.

Table 1. Study implementation period

Partisipant	Baseline (A1)	Intervention (B)	Baseline (A2)
Participant 1	3 weeks	5 weeks	7 weeks
Participant 2	4 weeks	7 weeks	4 weeks
Participant 3	5 weeks	7 weeks	3 weeks

Data were primarily collected through standardized oral reading assessments. Each reading passage utilized contained a variable length, ranging approximately from 350 to 400 words. Throughout the sessions, the researcher also conducted systematic observational recording of the participants' reading behavior, noting signs of reading difficulty, reluctance to continue the task, and any evidence of minimal self-regulation strategy use. To maintain novelty and avoid practice effects, a different reading passage with a distinct thematic focus was administered weekly, resulting in a total corpus of 15 unique reading texts over the study's duration.

The primary metric for quantifying reading achievement, specifically concerning accuracy assessment, often involves the Informal Reading Inventory (IRI) framework. Within this context, reading accuracy is precisely defined by the percentage of words correctly decoded by the reader, and this measure has been empirically established as a valid indicator of overall reading proficiency (Rasinski, 2004). Reading accuracy within the Informal Reading Inventory (IRI) framework is categorized into three critical levels based on the percentage of words correctly decoded: (Rasinski, 2004).

Table 2. Levels of performance for word decoding accuracy

Level	Scores
Independent Level	97% - 100%
Instructional Level	90% - 96%
Frustration Level	< 90%

Participant: The participants for this study were three totally blind 8th-grade students enrolled at SMPLB YPAB, a Special Junior High School located in Surabaya. They were selected using a purposive sampling technique based on the following inclusion criteria:

- Demonstrated voluntary consent to participate in the investigation.
- Exhibited documented limitations in foundational reading skills, specifically low Braille reading accuracy.
- Did not possess any co-occurring developmental or intellectual disabilities aside from total blindness.

Table 3. Demographics and participant profiles

Partisipant	Age	Gender	Impairment
Participant 1	14 years old	Male	Congenital Total Blindness
Participant 2	15 years old	Male	Congenital Total Blindness
Participant 3	14 years old	Male	Congenital Total Blindness

Data analysis

Visual analysis of graphic information is consistently employed as the most robust method for data interpretation within Single-Subject Research (SSR) designs (Lane et al., 2017; Neuman & McCormick, 1995; Rassafiani et al., 2025). Complementary to the visual analysis, the study quantified the magnitude of the intervention effect by calculating the Percentage of Non-Overlapping Data (PND). Based on the established criteria by Morgan & Morgan (2008), PND is interpreted as follows: PND exceeding 90% signifies a highly significant positive effect, PND between 70% and 90% implies a moderately effective outcome, PND between 50% and 70% suggests ambiguous or questionable treatment effects, PND falling below 50% indicates that the intervention produced no reliable change in the outcome measure.

Result

This study aimed to evaluate the efficacy of metacognitive strategies in enhancing Braille reading accuracy among students with visual impairments using a Single-Subject Research A-B-A design. The findings decisively demonstrate that the implementation of the metacognitive reading strategies yielded a functional impact on the participants' Braille reading accuracy. All three participants exhibited a marked increase in reading accuracy scores during the Intervention phase (B) when contrasted with both the initial Baseline (A1) and the subsequent Withdrawal/Return-to-Baseline phase (A2). The specific outcomes of the intervention are presented below:

Table 4. Braille reading accuracy scores

	Partisipant 1			**Partisipant 2**			**Partisipant 3**		
Week	Phase	Accuracy Scores	Level	Phase	Accuracy Scores	Level	Phase	Accuracy Scores	Level
1	Baseline (A1)	91,5%	Instructional	Baseline (A1)	93,9%	Instructional	Baseline (A1)	95%	Instructional
2		92,5%	Instructional		93,9%	Instructional		95,4%	Instructional
3		92,9%	Instructional		94,4%	Instructional		95,9%	Instructional
4	Intervention (B)	97,2%	Independent		94,8%	Instructional		96,4%	Instructional
5		97,2%	Independent	Intervention (B)	96,9%	Instructional		96,3%	Instructional
6		97,0%	Independent		97,6%	Independent	Intervention (B)	97,3%	Independent
7		97,2%	Independent		97,7%	Independent		97,7%	Independent
8		98,0%	Independent		98,0%	Independent		97,7%	Independent
9	Baseline (A2)	94,7%	Instructional		98,0%	Independent		98,2%	Independent
10		94,8%	Instructional		98,7%	Independent		98,2%	Independent
11		94,7%	Instructional		98,1%	Independent		98,4%	Independent
12		95,2%	Instructional	Baseline (A2)	96,5%	Instructional		98,5%	Independent
13		95,2%	Instructional		95,5%	Instructional	Baseline (A2)	96,3%	Instructional
14		95,3%	Instructional		95,5%	Instructional		96,3%	Instructional
15		95,2%	Instructional		95,5%	Instructional		96,3%	Instructional

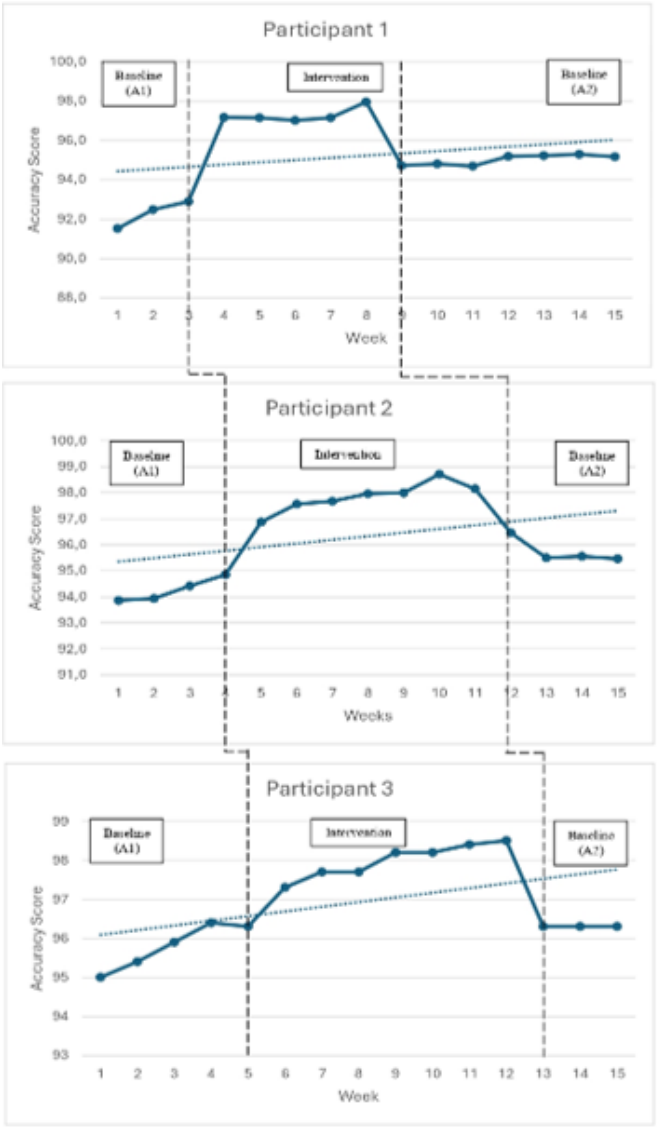

Figure 1. Visual graph analysis: Reading accuracy

Partisipant 1

During the initial Baseline phase (A1), spanning Weeks 1–3, the mean reading accuracy score was 92.30%. The performance data exhibited relative stability yet showed a minimal accelerating trend (ranging from 91.5% to 92.9%). Crucially, this level of performance remained within the Instructional Level category, indicating that the subjects required continuous support for successful text decoding. Immediately upon the introduction of the intervention (Week 4), a sharp, immediate change in performance level was observed, with accuracy surging from 92.9% to 97.2%. The overall mean accuracy score for the Intervention phase jumped to 97.32%. All measurement sessions conducted during Phase B were categorized as the Independent Reading Level (>97%), signifying that the subjects were capable of reading the text with high proficiency and without the need for teacher guidance. The data displayed exceptional stability at this elevated level, fluctuating minimally between 97.0% and 98.0%. Upon the discontinuation of the intervention in the baseline phase (A2) (Weeks 9–15), a reversal of effect occurred, evidenced by a decline in accuracy from its peak of 98.0% to 94.7%. The mean score for Phase A2 was 95.06%. Although the A2 mean was numerically higher than A1, the performance dropped from the Independent Level back into the Instructional Level category and remained stable within that range for seven consecutive weeks. A visual comparison of the data trends (see Figure 1) demonstrates that the subjects consistently achieved and maintained the desired Independent Reading Level solely during the presence of the Intervention phase (B). This pronounced drop in accuracy (reversal) observed upon the withdrawal of the intervention in A2 provides strong descriptive evidence of the intervention's functional control over the subjects' reading accuracy, effectively ruling out maturation or other extraneous variables as the primary cause of improvement.

Partisipant 2

The initial Baseline phase (A1), administered over Weeks 1–4, yielded a mean reading accuracy score of 94.25%. The data demonstrated high stability, with scores fluctuating minimally between a low of 93.9% and a high of 94.8%. Crucially, performance throughout this phase was consistently categorized at the Instructional Reading Level, confirming that Participant 2 was capable of adequate decoding but remained in the zone requiring teacher guidance for successful text engagement. Immediately upon the introduction of the intervention (Week 5), a sharp and immediate level change was observed, as the reading accuracy score surged from 94.8% to 96.9% in a single session. The overall mean accuracy score for Phase B climbed to 97.80%. Accuracy displayed a clear and consistent accelerating trend throughout Phase B, eventually peaking at 98.7% (Week 10). Significantly, all measurement sessions during the Intervention phase were categorized at the Independent Reading Level, indicating high proficiency and independent decoding capability.

When the intervention was withdrawn in Phase A2 (beginning Week 12), a clear reversal of the effect was immediately evident, with the score dropping from its Phase B peak (98.1%) to 96.5% in the first A2 session. The mean accuracy score for this phase was 95.75%. While this score remains quantitatively high, the performance reverted back to the Instructional Reading Level across all A2 sessions. The inter-phase comparison offers strong descriptive proof: high accuracy and the Independent Reading Level were only sustained when the intervention was actively implemented (Phase B). The subsequent decline in reading accuracy when the treatment was withdrawn demonstrates that the intervention was the causal factor controlling the change in reading accuracy for Participant 2.

Partisipant 3

The initial Baseline phase (A1), implemented over Weeks 1–5, yielded a mean reading accuracy score of 95.72%. The data showed a clear and consistent accelerating trend, starting at 95.0% and peaking at 96.4% (Week 4) before slightly dipping. This baseline trend hovered precisely around the 95% threshold, which typically delineates the Instructional and Independent Reading Levels. Despite the high initial accuracy, all sessions were strictly categorized as the Instructional Level, indicating that Participant 3, while proficient, still benefited from instructional support. Immediately following the introduction of the intervention (Week 6), a sharp level change was observed. Accuracy surged from 96.3% to 97.3% in a single session. The overall mean reading accuracy score for Phase B jumped to 97.87%. Reading accuracy demonstrated a clear, stable trend at a remarkably high level, peaking at 98.5% (Week 12). Crucially, all measurement sessions during this phase were classified at the Independent Reading Level. This successfully validated that the intervention was instrumental in propelling Participant 3's performance to the level of decoding independence. Upon the baseline phase (A2) (beginning Week 13), a clear reversal in performance was immediately evident, with accuracy declining from its intervention Phase peak of 98.5% to 96.3%. Reading accuracy subsequently stabilized at this 96.3% level until the conclusion of the study. Critically, Participant 3's performance in the baseline phase (A2) reverted to the Instructional Reading Level across all sessions. The simultaneous observation of a reduction in accuracy and a return to the Instructional Level immediately following the discontinuation of the metacognitive strategies provides strong evidence of the intervention's functional control over the participant 3's Braille reading accuracy.

Based on the evidence across the three experimental phases, the metacognitive reading strategy intervention is confirmed to be functionally effective in enhancing the Braille reading accuracy of all three participants, successfully elevating their performance from the Instructional Level to the Independent Reading Level. While minor natural accelerating trends were noted in some baselines Phase (A1), the drastic, immediate, and consistent change in performance level observed during the Intervention Phase (B), coupled with the subsequent reversal in baseline Phase (A2), provides conclusive visual support for the claim that the intervention was the primary causal factor influencing the observed improvement in Braille reading accuracy.

Effect size analysis (PND)

To substantiate the visual analysis, the Percentage of Non-Overlapping Data (PND) was computed for each participant. PND serves as a robust effect size metric in single-subject research, quantifying the percentage of data points in the Intervention phase (B) that exceed the highest score observed during the Baseline phase (A1). A high PND value is typically interpreted as evidence that the intervention exerted a significant functional influence on the target behavior (reading accuracy). The calculated PND values are presented in the following table:

Table 5. Percentage of Non-Overlapping Data (PND) of all participants

Participant	Maximum Baseline (A1)	Data Points in Intervention (B)	PND (%)	Interpretation
Participant 1	92.9	5/5	100.0	Very Effective
Participant 2	94.8	6/6	100.0	Very Effective
Participant 3	96.4	7/7	100.0	Very Effective

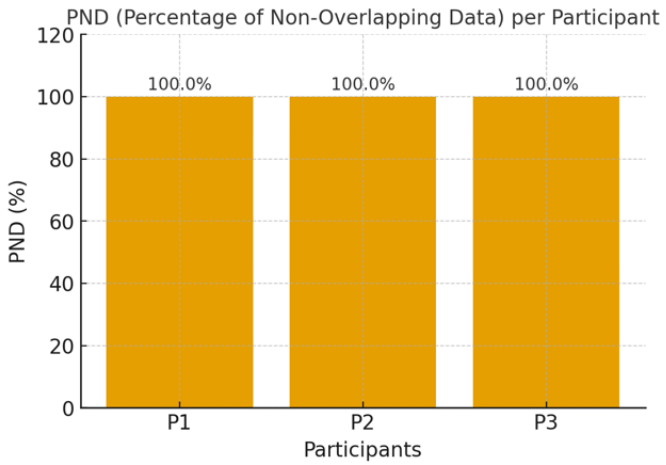

Figure 2. Percentage of Non-Overlapping Data (PND) of reading accuracy

The calculated Percentage of Non-Overlapping Data (PND) results provide robust quantitative substantiation for the visual analysis. The findings indicate that 100% of the data points recorded during the Intervention phase (B) exceeded the highest score achieved in the initial Baseline phase (A1) for all three participants. A PND value of 100% across all participants conclusively affirms that the metacognitive strategy intervention exerted a highly significant positive effect on improving Braille reading accuracy. This finding is entirely congruent with the visual analysis, which demonstrated an immediate and drastic level change from the Baseline to the Intervention phase, followed by a reversal effect upon treatment withdrawal in Phase A2. As illustrated in Figure 2, a 100% PND value confirms that all intervention scores surpassed the highest baseline score, thus categorizing the intervention as "highly effective" based on the established criteria for single-subject research effect size (Morgan & Morgan, 2008).

Discussion

The research findings clearly demonstrate that the implementation of metacognitive strategies significantly contributed to the change in reading accuracy among the students with visual impairments. All three participants consistently exhibited a positive, accelerating trend in reading accuracy throughout the Intervention phase. This visual evidence is further reinforced by the quantitative analysis utilizing the Percentage of Non-Overlapping Data (PND). The PND results, calculated at 100% for all participants, provide compelling objective proof that all scores recorded during the intervention phase exceeded the highest scores established during the baseline phase. This 100% PND value confirms the presence of a highly robust and reliable functional relationship between the metacognitive intervention and the observed improvements in Braille reading accuracy.

The calculated PND value of 100% confirms the intervention's categorization as "highly effective," based on the established criteria by Morgan & Morgan (2008), which designate a PND score of ≥90% as indicative of a significant effect. This quantitative result substantially reinforces the argument that metacognitive strategies exert a significant impact on improving Braille reading accuracy. Furthermore, these findings support the recommendations of Riley-Tillman et al., (2009), who advocate that single-subject research designs, when supplemented with quantitative effect size metrics such as PND, provide stronger empirical evidence regarding the efficacy of educational interventions. This methodological approach, therefore, robustly establishes the effectiveness of metacognitive instruction within the context of Braille literacy.

Analysis of the six reading error indicators (mispronunciation, omission, substitution, insertion, repetition, and self-correction) revealed that the metacognitive strategy instruction was most effective in significantly reducing repetition and substitution errors. This finding is consistent with the results reported by Chen et al (2023), who stated that enhanced phonological awareness and self-regulation are critical in mitigating these specific types of errors among Braille readers. During the intervention, the visually impaired students began to develop a heightened awareness of their own thinking and reading processes, particularly in recognizing errors that were previously unmonitored. This self-regulatory process directly impacted technical reading performance as the students' focus shifted from mere word-for-word decoding to active self-regulation in reading. This outcome aligns with existing literature asserting that metacognitive strategies, when adapted for readers with visual impairments, can positively influence academic achievement (Bhatti, 2024; Nannemann, 2021).

Metacognitive strategies have been shown to exert a significant positive effect within general reading contexts, particularly among secondary school students (Dignath & Büttner, 2008; Tun & Win, 2025; Xu et al., 2023). Strategies such as pre-reading planning, self-monitoring of key information, and post-reading self-evaluation have been empirically proven to enhance students' awareness and self-regulatory control over their entire reading process (Bouknify, 2023). This established efficacy strengthens the hypothesis that metacognitive instruction is highly applicable for improving Braille reading accuracy in students with visual impairments. This is due to the critical finding that reading accuracy is fundamentally influenced by the reader's ability to monitor and reflect upon phonological errors, substitutions, and omissions during the tactile decoding process.

Specifically, the planning and evaluating components of the metacognitive instruction appear to have contributed dominantly to the observed increase in reading accuracy. By being guided to formulate reading goals, anticipate decoding challenges, and re-evaluate reading outcomes, students were able to significantly reduce error types such as insertion and omission. This finding reinforces the perspective offered by Mokhtari & Reichard (2002), which posits that metacognitive components do not solely influence comprehension but are also critical in regulating and improving technical reading accuracy.

The utilization of the A-B-A single-subject design significantly enhances the internal validity of this investigation. The observed pattern—where performance systematically shifts during the intervention phase and subsequently stabilizes upon return to the baseline phase (A2)—serves as potent evidence that the improvement in reading accuracy scores is a direct result of the intervention, rather than attributable to the participants' natural developmental progress. Riley-Tillman et al. (2009) affirm that the A-B-A design is particularly well-suited for educational interventions involving special populations, as it enables the in-depth, intensive observation of individual behavioral change.

Theoretically, these findings significantly broaden the scope of metacognitive theory, extending its relevance from the conventional domain of text comprehension to encompass the technical aspects of decoding, specifically Braille reading accuracy. This outcome is highly relevant to the foundational work of Flavell (1979), which posited that metacognition involves not only control over the *content* of thought but also the regulation of the thinking *process* comprehensively. Furthermore, the effectiveness of the strategies employed in this study proves that metacognition is not exclusive to visual readers but can be effectively adapted and applied to tactile readers.

Conclusion

This investigation conclusively demonstrates that the implementation of metacognitive strategies yields a significant functional impact on enhancing reading awareness and Braille reading accuracy scores among students with visual impairments. Although minor accelerating trends were observed during some Baseline phases (A1), the drastic, immediate, and consistent level change observed in the Intervention phase (B), coupled with the subsequent reversal in Baseline Phase (A2), provides robust visual evidence supporting the claim that the intervention was the primary causal factor influencing the improvement in Braille reading accuracy. Overall, metacognitive strategies proved effective in fostering reflective thinking patterns and promoting self-correction mechanisms during Braille decoding. This capability is established as an essential prerequisite for improving comprehension and furthering the learning autonomy of students with visual impairments. Ultimately, the metacognitive strategy-based instructional approach enables students to move beyond mere technical reading, empowering them to comprehend, evaluate, and control their entire cognitive process in a more independent and meaningful.

Declarations

Acknowledgments

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collegues, students, teachers, and school administrators.

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Ethics statements

The authors affirm that the research adheres to ethical guidelines, particularly concerning the rights and welfare of human participants.

The procedures involving human subjects were in accordance with the ethical standards of the institutional and national research committees and with the 1964 Helsinki declaration and its later amendments. Informed consent was obtained from the participants (and/or their legal guardians) prior to the commencement of the study.

Conflict of interest

The authors declare that there are no competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Informed consent

Informed consent for participation in the study was obtained from the participants (8th-grade students with visual impairments) voluntarily, and from their legal guardians, prior to the research being conducted. The participants were selected based on the criteria that they demonstrated voluntary consent to participate in the investigation.

Data availability

The datasets generated and analyzed during the current study (specifically the Braille Reading Accuracy Scores presented in Table 4) are available from the corresponding author upon reasonable request.

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