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Boosting Verbal Memory Capacity in Elementary School Students : A Face to Face Intervention Study

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Abstract: This study aims to measure the effectiveness of non-technological working memory interventions in improving the verbal working memory capacity of a third-grade student, who experiences learning difficulties in reading comprehension and maintaining focus in class. The research employed a qualitative approach using a single-case reversal design (A1BA2) over 12 sessions. The intervention focused on enhancing D's phonological loop function through face-to-face, non-digital working memory training exercises, such as the odd one out and listening recall tasks. Data were collected through semi-structured interviews with parents and teachers, as well as non-participatory observations in both school and home environments. Data analysis involved comparing pre- and post-intervention performance to identify changes in working memory abilities. The findings indicate that this intervention can enhance verbal working memory capacity, supporting improvements in reading comprehension and focus. This suggests that non-technological, easily implementable interventions can provide a practical solution for enhancing cognitive abilities in children, particularly those from low socioeconomic backgrounds, with potential long-term benefits for academic performance.

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Introduction

Working memory is a cognitive process that allows individuals to temporarily store and manipulate information, using it to complete complex tasks (Cockcroft, 2015; Klingberg et al., 2002). It enables individuals to process and comprehend new information, follow instructions, recall, and apply existing knowledge (Jaroslawska et al., 2016). Working memory plays a crucial role in managing and storing information required to achieve specific goals while filtering out irrelevant stimuli or distractions from other sources (Hofmann et al., 2012; Schmeichel et al., 2008). Additionally, working memory is a strong predictor of various complex cognitive skills associated with academic achievement (Alloway & Copello, 2013; Khalid et al., 2019; Peng et al., 2018), such as reading comprehension (Borella & De Ribaupierre, 2014), mathematical problem solving (Bull & Lee, 2014; Friso-van Den Bos et al., 2013), remembering instructions, and planning future learning activities (St Clair-Thompson et al., 2010).

Previous research has established a positive correlation between working memory and self-regulation skills, such as attention (Diamond & Ling, 2019), inhibitory control (Engle, 2002), and emotion regulation (Xiu et al., 2018). Consequently, individuals with learning difficulties, self-regulation challenges, and attention deficits often experience working memory impairments, as they struggle to control misaligned behaviors, process, and integrate relevant information effectively, leading to variations in learning approaches (Grégoire et al., 2012; Martinussen et al., 2005; Olesen et al., 2004; Xiu et al., 2018).

Research indicates that working memory development is influenced by family socioeconomic status (SES) (Rosen et al., 2020). On average, children from low socioeconomic backgrounds exhibit lower working memory performance compared to those from higher SES backgrounds (Lawson et al., 2018; Rosen et al., 2020). One mechanism explaining this difference is deprivation, characterized by limited cognitive stimulation and social experiences from the environment, which are essential for supporting the development of neural systems underlying higher cognitive capacities (McLaughlin et al., 2021; Sheridan & McLaughlin, 2014). Children from low-SES backgrounds typically receive less cognitive stimulation than those from higher SES families (Rosen et al., 2020). This lack of stimulation often hinders the development of executive functions, such as working memory, self-control, and cognitive flexibility, ultimately leading to lower performance in tasks requiring these functions (Amso & Lynn, 2017; Hackman et al., 2015; Rosen et al., 2018).

Working memory integrates information from long-term memory with new information being processed in temporary storage (Swanson & Beebe-Frankenberger, 2004). This process frequently occurs during classroom learning activities, and children with limited working memory capacity often struggle to engage in learning (St Clair- Thompson et al., 2010). Limitations in working memory can lead to various learning difficulties, as it acts as a bottleneck in reinforcing a child's understanding and knowledge, causing them to fail in meeting the demands of tasks requiring sustained memory use, which results in suboptimal development of skills and knowledge throughout their schooling years (Alloway, 2006; Gathercole et al., 2004).

Research indicates that approximately 15% of children have limited working memory, leading to poor focus, distractibility, and difficulty completing tasks requiring sustained attention (Holmes et al., 2010). Over 80% of children with these limitations also face challenges in reading and mathematics, but are often not identified as having special educational needs. Therefore, it is crucial to understand and provide appropriate interventions to improve working memory, given its critical role in supporting children's academic development (Holmes et al., 2010; Holmes & Gathercole, 2014).

This case study examines an 8-year-old third-grade male student who came from a low SES background who was reported by his teacher and parents to be experiencing learning difficulties. He struggles to follow classroom lessons, takes longer to comprehend reading material, and requires repetition to understand lessons, particularly in noisy environments. It was also noted that D has a history of speech delay and received limited stimulation during early development. Cognitive assessments revealed significant discrepancies between his verbal and non-verbal abilities. Overall, D's intelligence falls within the average range (Full Scale IQ = 96, WISC-4), with non-verbal abilities categorized as superior (Category 1). These findings suggest that D's challenges are not due to general intellectual limitations.

The disparity between verbal and non-verbal abilities is more apparent in the results of the simple span test. On the subtests measuring verbal working memory capacity (Alloway 2007; Wechsler 2009), D scored lower, whereas on subtests assessing working memory performance in visual and spatial tasks (Pickering et al., 2001), D achieved higher scores. The differences in D's verbal and non-verbal test results can be explained using the working memory model of Baddeley and Hitch (1974), which consists of the central executive and two domain-specific storage systems: the phonological loop and visuospatial sketchpad (Baddeley & Logie, 1999). Verbal tasks require simultaneous storage and processing of information, relying on both the phonological loop and central executive (Baddeley & Hitch, 1974; Park et al., 2013). The phonological loop is responsible for short-term verbal

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information storage, while the central executive manages attention, allocates memory resources, and regulates the flow of information into working memory (Baddeley, 2003). In this case, a limited phonological loop capacity impairs D’s ability to manipulate and process verbal information, impacting their verbal IQ score. Conversely, the stronger visuospatial sketchpad supports D's superior performance on non-verbal tasks involving visual and spatial relations (Kuschner, 2013).

The discrepancy in verbal and non-verbal performance may also be influenced by environmental factors. Verbal tests are often linked to prior knowledge and early language experiences, which might have been limited, thus lowering the verbal IQ score (Brooks-Gunn et al., 1996; Hoff & Tian, 2005). In contrast, non-verbal tests, which are less dependent on language experience and prior knowledge, allow the student to demonstrate their full potential.

In recent years, working memory intervention programs aimed at improving working memory capacity have commonly utilized technology as the medium for intervention (Diamond, 2012; Karbach & Unger, 2014; Melby-Lervåg & Hulme, 2013; Strobach & Karbach, 2016). These programs focus on enhancing cognitive functions through repeated practice with tasks involving working memory. Structured and progressive training is expected to develop working memory capacity (Bryck & Fisher, 2012; Jolles & Crone, 2012). However, a significant challenge in implementing technology-based interventions is the limited access for children from low socioeconomic status (low SES) families, particularly in developing countries like Indonesia. Limited access to devices such as computers and the internet often hinders the use of technology in working memory interventions (Munir et al., 2023). Consequently, children from low SES families are less exposed to opportunities that support their cognitive development (Amso & Lynn, 2017). Most current working memory intervention programs use app-based technology, but there is still a lack of research exploring the development of working memory interventions for low SES children that do not rely on technology in Indonesia.

This study offers a more inclusive and practical solution by focusing on face-to-face working memory training that can be implemented in schools by teachers or at home by parents, without the need for technological devices. Unlike most current working memory interventions that rely heavily on technology, this approach provides an affordable and accessible alternative for a wider range of children, particularly those from low SES families who often have limited access to such technology. The purpose of this research is to investigate the effectiveness of non-technological interventions in improving working memory capacity related to the phonological loop. The intervention, adapted from Henry et al. (2014), aims to improve working memory capacity related to the phonological loop through face-to-face, non-computerized, quick, and simple working memory training. The intervention focuses on direct and near transfer effects, which are improvements in both the trained tasks and related untrained tasks, specifically in working memory abilities for monitoring and updating information. These skills form the foundation for improving reading comprehension (Hulme & Starling, 2010), allowing children to select and retain relevant information while suppressing irrelevant information during reading tasks (García-Madruga et al., 2016). Hence, children may develop foundational scholastic skills that benefit their overall learning process (Henry et al., 2014).

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Research Method

This study utilized a qualitative single-case study approach with a reversal design (A_1BA_2) (Kratochwill & Levin, 2014). The design involved measurements in three consecutive phases: A_1) the initial baseline measurement phase, B) the intervention phase, and A_2) the follow-up measurement phase to assess the changes resulting from the intervention (Freeman et al., 2010). The participant was an eight-year-old child (D) who struggled with reading comprehension and had difficulty staying focused in class. To gain further insights, semi-structured interviews were conducted with the parents and teachers during phase A_1, in addition to the ongoing measurement and observation activities throughout the intervention. The working memory training intervention lasted for six weeks, with a total of 12 sessions. Two sessions were dedicated to baseline recording, followed by 10 intervention sessions, and concluding with an evaluation session. Each intervention session lasted between 15 to 20 minutes, with two sessions held per week.

Table 1. Intervention Activity Design

Session	Activity	Tasks Used	Notes
A1	Baseline measurement of phonological loop capacity and interviews with parents and teachers	1. Digit Span (Forward and Backward) 2. Listening Recall 3. Odd One Out Span	Task difficulty was gradually increased once the participant achieved relatively stable scores.
1-10	Working memory training	1. Listening recall. 2. Odd one Out Span.	
A2	Post-intervention evaluation of phonological loop capacity	1. Digit Span (Forward and Backward) 2. Listening Recall 3. Odd One Out Span	

The baseline measurement of working memory capacity related to verbal tasks (phonological loop and central executive) was conducted using two types of tasks: simple span tasks and complex span tasks, both designed to assess working memory capacity by requiring simultaneous storage and processing of information (Cockcroft, 2015).

The simple span task was measured using the forward and backward Digit Span subtests from the WISC-4 (Alloway, 2007; Sankalaite et al., 2023), In this task, participants were asked to repeat a series of digits in the correct order (forward) and in reverse order (backward), with the number of digits gradually increasing as the task progressed. The complex span task was measured using two tasks: Listening Recall (Alloway, 2007) and Odd one out span (Cragg et al., 2017). The Listening Recall task assessed the capacity of both the central executive and the phonological loop by asking participants to evaluate the meaning of a series of sentences and then recall the last word of each sentence (Cockcroft, 2015). Participants listened to sentences that were either logical or nonsensical (e.g., "The candle melts when heated" and "The pineapple plays soccer"). They were instructed to judge whether the sentences were 'true' or 'false' and then recall the last word of each sentence. The task began with one sentence and increased to five sentences. When dealing with two or more sentences, participants were required to evaluate the truth of each sentence before hearing the next one. After all the sentences were presented, they had to recall the last words in the

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correct order. If participants made three or more errors in a block, the trial was terminated. The total number of correct trials was recorded and used as a baseline for the intervention.

In the Odd One Out Span task, participants were shown cards displaying three shapes, two of which were identical and one that was different. They were asked to identify the different shape and remember its position (left, center, or right) (Cragg et al., 2017). The difficulty increased by presenting multiple cards simultaneously, after which the participants were required to recall the positions of the different shapes on each card in the order they had been presented. The total number of correct trials was recorded, and this data served as the baseline for working memory in the intervention.

The intervention sessions involved repetitive practice using two tasks: Listening Recall and Odd One Out Span (Henry et al., 2014). These complex span tasks assess working memory by engaging both the phonological loop and central executive, combining the simultaneous processing and storage of information (St Clair- Thompson et al., 2010). Such tasks are known as Executive-Loaded Working Memory (ELWM) tasks, as they require both processing and storage of information concurrently, thereby engaging the central executive beyond short-term storage (Miyake & Friedman, 2012).

The data analysis technique employed in this study involved comparing pre- and post-intervention performance to evaluate changes in working memory capacity. Data were collected from the results of the Listening Recall and Odd One Out Span tasks during both baseline and post-intervention phases. The performance data were analyzed by calculating the participant’s scores on each task and identifying any improvements. Additionally, qualitative data from semi-structured interviews with parents and teachers were thematically analyzed to explore changes in the participant’s behavior, focus, and cognitive abilities, as well as to understand the underlying factors that contributed to the participant’s condition.

Results and Discussion

This study aims to measure the effectiveness of non-tecnological working memory interventions in improving verbal working memory capacity, of a third-grade student, D (8). Based on interview and observation results, it was found that D experienced limited cognitive and language stimulation during early developmental years due to both parents working full-time. As a result, D often spent time watching videos on the internet, which contributed to delayed speech development and impacted verbal information processing and focus in learning. At school, D frequently struggled to follow lessons, needed repeated instructions, and was slow in taking notes, especially in crowded classrooms. At home, D was also easily distracted and found it difficult to maintain focus on tasks. The lack of early stimulation is suspected to be the primary factor affecting D's working memory development and academic abilities.

The intervention lasted for 12 sessions over six weeks, with each session lasting 15 to 20 minutes at the participant's home, scheduled between 8 AM and 11 AM to accommodate the school timetable. Each session began with rapport building to ensure D’s readiness to engage in the intervention. Sessions A1 and A2 were used to assess pre and post-intervention capabilities, involving three tasks: Odd One Out, Listening Recall, and Forward-Backward Digit Span. Following these, ten intervention sessions were conducted twice a week, focusing on the Odd One Out and Listening Recall tasks.

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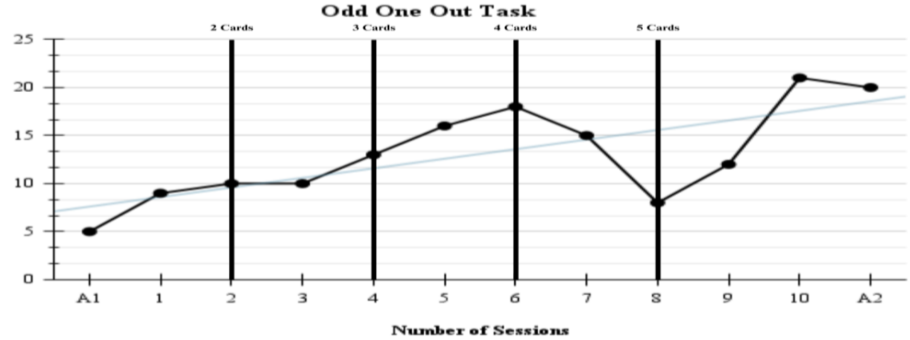

Figure 1. Results of the Odd One Out Task Intervention

In the Odd One Out task, the participant identified the item that differed from several similar items and remembered its position. The difficulty level increased by adding more cards displayed before the participant responded. Scores were obtained based on the number of correct answers before D made more than three mistakes. D started the Odd One Out task with a score of five during the first baseline session (A1) at the one-card difficulty level. After two sessions with relatively stable scores, the difficulty level was increased to two cards, and progressively increased to four cards, where D consistently showed score improvement.

However, when the difficulty level was raised to five cards, D experienced a drop in scores during the first two sessions. The decline in the first session was likely due to D adjusting to the more complex memory load compared to the previous difficulty level. In the second session, the lower score was thought to be influenced by D's physical and mental condition, as D appeared tired and less focused. This might be related to the intervention being conducted in the afternoon to fit D's schedule. During the intervention, D was visibly unfocused and yawned frequently, even though D had been asked beforehand if they wanted to proceed with the intervention that day.

In the following intervention sessions, D's scores improved after the intervention was rescheduled to the morning, as before. By the final intervention session, the difficulty level remained at five cards, and in the last session, D achieved a significant score increase, surpassing 20 points. Overall, there was a trend of increasing scores proportional to the task's difficulty level.

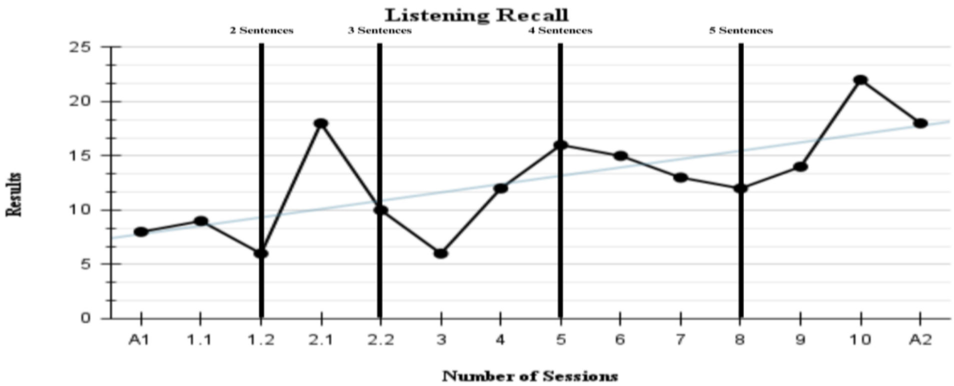

Figure 2. Results of the Listening Recall Task Intervention

In the listening recall task, the participant was asked to judge the truth of a sentence and then recall the last word of the sentence. The difficulty increased by adding more sentences. During the baseline session, D scored 8 at the one-sentence difficulty level.

In the first and second intervention sessions, the examiner introduced two difficulty levels because D appeared eager to participate. The goal of this increase was to provide a

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challenge and assess D's performance on more complex verbal tasks compared to the previous difficulty level. In session 1.1, D's performance improved compared to the baseline, so the difficulty was increased to two sentences in session 1.2. However, there was a drop in the score to 6, as D needed more time to recall, especially the last word of each sentence. Despite this, D was still able to correctly recall the words.

In the second session with the two-sentence difficulty, D showed significant improvement, scoring 18. D seemed to remember the two requested words more easily and focused on listening to the sentences. Since D remained focused, the examiner increased the difficulty to three sentences, but D's performance dropped again, with the score returning to 10. In subsequent intervention sessions, D gradually improved performance at the same difficulty level. However, when the difficulty increased further, D's performance declined again, particularly in the eighth session, where the lowest score was recorded since the introduction of the four-sentence difficulty level. During this session, D was slower in responding and appeared fatigued. Nonetheless, D's scores gradually improved in the remaining intervention sessions.

Tabel 2. Results of Digit Span test

	Forward Digits Span	Backwards Digits Span
A1	4	3
A2	7	6

In the digit span task, the participant was asked to repeat a sequence of numbers in the same order (forward) and in reverse order (backward) as presented by the examiner. This task was administered during both the baseline measurement (A_1) and post-intervention (A_2).

In session A_1, D appeared to focus on the task by looking upwards and achieved a score of 4 on the forward digit span and 3 on the backward digit span. D's difficulty in responding was related to accurately recalling the number sequence, often resulting in D providing answers in a random order.

The results from the intervention demonstrated an improvement not only through direct transfer effects on the trained tasks, such as Odd One Out and Listening Recall, but also through near transfer effects on the untrained digit span task. These findings support the literature, which suggests that Executive-Loaded Working Memory (ELWM) tasks, such as Odd One Out and Listening Recall, have a direct effect in enhancing working memory on the tasks that are directly trained (Rowe et al., 2019) as well as on other tasks that are not directly trained (Alloway et al., 2013; Gray et al., 2012; Henry et al., 2014; Holmes et al., 2009).

The improvement observed in both direct and near transfer effects can be attributed to the ELWM tasks used in the intervention. These tasks not only focus on information storage but also engage the participant's ability to manage attention and process information simultaneously, thus training executive functions that contribute to skill transfer to similar tasks (Henry et al., 2012, 2014; Rowe et al., 2019). By utilizing tasks that require the coordination of information storage and processing at the same time, the intervention increases the likelihood that the acquired skills can be applied to other tasks with similar demands (Gathercole et al., 2019).

Previous research has indicated that regular practice with ELWM tasks can improve the efficiency of information processing and facilitate the storage of information in working memory, thereby enhancing working memory abilities that are beneficial for children's scholastic performance (Henry et al., 2014; Loosli et al., 2012). As previously explained,

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when performing ELWM tasks, attention is divided between information storage and processing. This resembles how attention functions in everyday activities, helping to form new cognitive habits. Since training tends to impact similar activities, ELWM training can enhance untrained working memory abilities and everyday skills, such as attention and language, through both near and far transfer effects (Gathercole et al., 2019). Additionally, the adaptive working memory load adjusts to the child's performance, allowing the child to remain challenged without becoming overwhelmed (Melby-Lervåg & Hulme, 2013).

D's early developmental history, in which most of the time was spent in front of gadget screens, can also explain D's difficulties in tasks requiring verbal abilities and the speech delay that D experienced. Excessive use of gadgets in children can negatively affect working memory abilities (Soares et al., 2021). The time spent in front of screens, replacing direct interaction, may impact the development of the phonological loop, which plays a crucial role in processing verbal information (Veraksa et al., 2021). These findings are consistent with the observation that the duration of gadget use and screen exposure are primary predictors in identifying speech delay in children (Lin et al., 2015).

The findings of this study reinforce the conclusions of Mora & Borella (2015), which assert that working memory is not a fixed entity, as earlier studies suggested (Klingberg et al., 2002), but can be modified through targeted training. Furthermore, these findings support previous research that indicates working memory training interventions can have positive effects on other related, untrained working memory skills (Alloway, Bibile, & Lau, 2013; Gray et al., 2012). This is attributed to the nature of Executive-Loaded Working Memory (ELWM) tasks, which are more closely tied to broader cognitive abilities compared to simple short-term memory tasks (Loosli et al., 2012).

From a practical standpoint, this intervention offers an accessible solution for schools and families that may not have access to technology or app-based programs to enhance working memory capacity. Teachers and parents can easily implement simple exercises, such as Listening Recall and Odd One Out Span, at home or in school, without the need for special devices. Furthermore, the short and quick nature of the intervention sessions makes it feasible to integrate into daily routines, allowing children, especially those from low socioeconomic backgrounds, to benefit equally from cognitive and academic improvements.

Conclusion

This study demonstrates that a face-to-face, non-computer-based working memory intervention, which is easy and quick to implement, shows improvement in verbal working memory capacities, as evidenced by increased scores in the tasks provided. These improvements are evidenced by increased scores in verbal tasks, supporting better reading comprehension and focus. Repeated practice on ELWM tasks, with difficulty levels adjusted to the child's abilities, resulted in both direct and near transfer effects post-intervention. These findings suggest that simple, gadget-free interventions conducted regularly can positively impact verbal working memory, which is expected to contribute to the child's scholastic abilities as they continue their learning journey.

Recommendation

This study has limitations in that it involved only a single-case sample. Therefore, it is recommended to use a quantitative method by increasing the number of participants in future research and dividing them into control and treatment groups. This approach aims to ensure whether the intervention effects observed can show similar significance in populations with

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similar demographics. Additionally, it is necessary to measure reading comprehension ability before and after the intervention to assess the improvement. A follow-up period of 3-6 months after session A2 is also recommended to measure the long-term effects of the intervention on the trained abilities (Henry et al., 2014). It is further suggested to increase the number of intervention sessions to a minimum of 18 sessions or three times per week to evaluate the improvement in working memory abilities with a more intensive intervention schedule.

Based on the findings, teachers are encouraged to collaborate with school counselors or learning support staff to identify students with verbal working memory challenges, such as difficulty with reading comprehension or focus. Once identified, these students can be supported through one-on-one or in small group sessions working memory exercises, such as Listening Recall and Odd One Out Span. These exercises can be tailored to each student's specific needs and adjusted in difficulty as they make progress. Parents can contribute by practicing similar exercises at home for 10-15 minutes per session, two to three times a week, and fostering cognitive development through early stimulation and limiting passive screen time, promoting interactive activities like reading and memory games. Collaboration between teachers, support staff, and parents is essential to ensure that the interventions are reinforced and the child's progress is monitored holistically.

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