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EFFECTIVENESS OF WORKING MEMORY IN CHILDREN WITH LEARNING DISABILITY

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ABSTRACT
BACKGROUND: Specific Learning Disabilities (SLDs) are neurodevelopmental disorders that hinder a child's ability to read, write, or perform math despite normal intelligence and adequate education. Common types include dyslexia, dysgraphia, and dyscalculia, often linked to deficits in cognitive processes like working memory. These difficulties affect academic performance, self-esteem, and emotional well-being. While traditional interventions focus on remedial teaching, they often overlook cognitive deficits. Working memory plays a crucial role in learning, and training programs targeting it have shown promise in improving memory and short-term academic skills. However, most studies are from Western settings, with limited research in diverse contexts like India. Given the high and varied prevalence of SLDs in India, this study aims to evaluate the impact of a structured working memory training program on cognitive and academic outcomes in Indian children with SLDs through a randomized controlled trial. **Objective** the present study aims to evaluate the effectiveness of a structured working memory training program on cognitive and academic outcomes in children diagnosed with Specific Learning Disabilities through a randomized controlled trial. **Methodology:** This 8-month experimental study was conducted with ethical approval and informed parental consent. Twenty children aged 6–15 years, with Learning Disability Checklist scores between 60 and 80, were randomly assigned into two groups: Group A (intervention, n=10) and Group B (control, n=10). Group A received a structured cognitive training program for three months, including Brain Gym, Frenkel's lower limb exercises, memory recall tasks, and visual-motor coordination activities, delivered in 45-minute individual sessions. Group B received motor skill training exercises without additional cognitive intervention. The Digit Span Test (Forward and Backward) was used as the outcome measure to assess attention, immediate memory, and working memory capacity. **Result:** total of 20 children were enrolled, with 10 in each group. Baseline Digit Span scores were comparable. After three months, Group A (intervention) showed significant improvements: Digit Span Forward increased by 2.6 points and Backward by 2.2 points (both $p = 0.0001$). Group B (control) had a modest 0.5-point gain in Forward ($p = 0.015$) and a non-significant 0.5-point increase in Backward ($p = 0.2987$). Post-test comparisons showed Group A significantly outperformed Group B in both Forward ($p = 0.0077$) and Backward ($p = 0.0073$) scores, indicating the effectiveness of cognitive training on working memory. **Conclusion:** the findings from our study support the effectiveness of cognitive-based working memory training in children with learning disabilities. These results, when considered alongside previous research, suggest that cognitive training programs can play a crucial role in educational and therapeutic contexts. Future research should include long-term follow-up, larger sample sizes, and comparisons between different training modalities to determine the most effective approaches for sustained cognitive improvement.
KEYWORDS: Learning disability, cognitive training, brain gym exercise, digit span forward and backward test, children, memory,motor skill training.

INTRODUCTION

Specific Learning Disabilities (SLDs) are a group of neurodevelopmental disorders that significantly interfere with a child's ability to acquire and use academic skills such as reading, writing, and mathematics. These disorders include dyslexia (reading disorder), dysgraphia (writing difficulties), and dyscalculia (mathematics disorder), and are not due to low intelligence, sensory impairments, or lack of educational exposure but instead stem from deficits in specific cognitive processes such as working memory and executive functioning [1].
Despite normal or above-average intelligence, children with SLDs struggle in school environments, often requiring specialized interventions and support.
The exact cause of SLDs is not entirely understood, but current research supports a multifactorial etiology that includes genetic, neurological, and environmental components. Family and twin studies have established a hereditary component, especially for dyslexia, with first-degree relatives more likely to be affected [2]. Neuroimaging findings in children with learning disabilities have revealed atypical brain activation patterns,

especially in regions associated with language, memory, and attention [3]. Environmental contributors such as prenatal complications, low birth weight, exposure to neurotoxins, and early deprivation also play a role in the development and severity of learning disabilities [4].

Children with SLDs typically experience persistent academic difficulties despite consistent instruction and motivation. Dyslexia is characterized by difficulties in word recognition, decoding, and spelling. Dysgraphia affects handwriting, coherence in written expression, and spelling, while dyscalculia involves problems with number sense, arithmetic skills, and understanding math concepts [5]. These challenges can have long-term effects on academic achievement, self-esteem, and social-emotional development. Many children experience anxiety, frustration, and isolation due to repeated academic failure and misunderstanding by peers and educators.

Globally, SLDs affect a significant portion of the school-aged population. The prevalence is estimated to be between 5% and 15%, depending on diagnostic criteria and sample populations [6]. In the United States, around 9.7% of children between the ages of 3 to 17 are diagnosed with learning disabilities [7]. The prevalence in India varies widely in literature, ranging from 2.16% to as high as 30.77% due to differences in screening tools and methodologies. The pooled prevalence of SLDs in Indian children to be around 8%, with higher prevalence rates among urban schoolchildren [1]. These statistics highlight the growing burden of learning disabilities and the need for tailored interventions that address the specific cognitive deficits associated with them.

Traditional interventions for SLDs focus primarily on remedial teaching, curriculum modification, and educational accommodations. While these are essential, they often do not target the underlying cognitive mechanisms responsible for the learning difficulties. Increasing attention has been given to the role of cognitive processes such as working memory in learning. Working memory, the brain’s ability to hold and manipulate information over short periods, plays a crucial role in academic tasks such as reading comprehension, mental math, and written expression [8]. Deficits in working memory are commonly observed in children with SLDs, suggesting that targeting this area through cognitive training may yield improvements not only in memory function but also in academic performance [9].

Working memory training programs involve engaging tasks that are designed to improve attention span, information retention, and mental processing through repetitive and adaptive activities. These programs are often computer-based and can be customized to suit individual learning needs. Recent research suggests that cognitive training interventions can lead to measurable improvements in verbal and visuospatial working memory in children with learning disabilities [9]. Working memory training had a moderate effect on improving cognitive skills and short-term academic performance in children with SLDs, with some benefits sustained up to several months after the intervention [10]. However, these interventions have yielded mixed results when applied in real-world educational settings, and questions remain regarding their long-term effectiveness and generalizability.

Motor skill training involves practicing and refining specific movements or actions to improve coordination, balance, and overall physical function. It helps in improved focus and concentration, enhance learning and retention. Moreover, much of the existing research on working memory training has been conducted in Western populations. Cultural and linguistic differences, educational infrastructure, and familial involvement can influence intervention outcomes. In India, where educational settings are highly diverse, there is a notable lack of research examining the effectiveness of cognitive interventions like working memory training in children with SLDs. Given the high prevalence of learning disabilities and the cognitive deficits associated with them, there is a clear need for contextually appropriate and evidence-based approaches.

The current gap in literature highlights the importance of testing these interventions in diverse populations, including Indian children with SLDs. Therefore, the present study aims to evaluate the effectiveness of a structured working memory training program on cognitive and motor skill training in children diagnosed with Specific Learning Disabilities through a randomized controlled trial.

2.METHODOLOGY AND MATERIALS

STUDY DESIGN: Pretest-posttest experimental study design
STUDY SETTING: Brain tree child developmental center, valasaravakam ,Chennai.
SAMPLE METHOD: Convenient sampling method
SAMPLE SIZE AND DURATION: 20 children

This study is a randomized controlled trial designed to evaluate the effects of working memory training in children with learning disability .The participants were selected based on specific inclusion and exclusion criteria and were randomly assigned to intervention group and control group

INCLUSION CRITERIA

- Children of both gender
- Children aged between 6 and 15 years
- Score between 60 and 80 in digit span test
- children had no visual or hearing impairments that could affect learning

EXCLUSION CRITERIA

- Non-cooperative children
- Those diagnosed with other neurological conditions such as Autism or Attention Deficit Hyperactivity Disorder (ADHD)
- Children with a digit span test score below 60 or above 80
- Children outside the specified age range

INTERVENTION PROTOCOL

This experimental study was conducted over a period of eight months at the Paediatric Physiotherapy Department, Brain Tree Child Developmental Centre, Valasaravakkam. Ethical approval was obtained from the Institutional Ethical Committee prior to the commencement of the study. Written informed consent was collected from the parents or guardians of all participants after explaining them the importance of the study and having cleared all their doubts.

A total of 20 children were recruited using a simple random sampling method. Based on a computer-generated randomization table, the participants were equally allocated into two groups: Group A (intervention group, n = 10) and Group B (control group, n = 10). Each participant was enrolled in the study for a duration of three months.

Children aged between 6 and 15 years, of either gender, with a score between 60 and 80 on the Learning Disability Checklist assessment were included in the study. These children had no visual or hearing impairments that could affect learning. Exclusion criteria were children who were non-cooperative, those diagnosed with other neurological conditions such as Autism or Attention Deficit Hyperactivity Disorder (ADHD), those with a checklist score below 60 or above 80, and those outside the specified age range.

Group A (Intervention group) received a structured cognitive training program that included:

- **Brain Gym and Hemispheric Integration Exercises**: Activities such as cross-crawling and bilateral coordination exercises to stimulate both hemispheres and improve attention and integration.

1. Cross Crawl
Therapist Position: Standing or sitting beside the child to guide and support.
Child Position: Standing or sitting comfortably with feet shoulder-width apart.
Repetitions: 10-15 repetitions on each side.
Time: 2-3 minutes.
Description: The child is intructed to march in place and to touch their right hand to their left knee and then their left hand to their right knee. This exercise promotes bilateral coordination and integration.

2. Lazy 8s
Therapist Position: Demonstrating the exercise in front of the child.
Child Position: Standing or sitting comfortably with eyes focused on a point in front of them.
Repetitions: 3-5 repetitions with each hand.
Time: 3-5 minutes.
Description: The child instructed to draw a figure-eight pattern in the air with their hand, first with one hand and then with the other. This exercise enhances visual tracking and coordination.

3. Hook-Ups
Therapist Position: Guiding the child into the correct position.
Child Position: Sitting cross-legged with arms crossed at wrists and fingers interlaced.
Repetitions: Holding the position for a few minutes.
Time: 2-5 minutes.
Description: The child instructed to sits cross-legged, crosses their arms at wrists, interlaces fingers, and draws their hands towards their chest. This exercise promotes relaxation and reduces stress.

4. The Elephant
Therapist Position: Demonstrating the exercise.
Child Position: Standing with one arm extended like an elephant's trunk.
Repetitions: 3-5 repetitions on each side.
Time: 2-3 minutes.
Description: The child instructed to draw large circles in the air with their extended arm, promoting balance and coordination.

5.Double Doodle
Therapist Position: Providing paper and crayons.
Child Position: Sitting comfortably with crayons in both hands.
Repetitions: Drawing shapes and patterns simultaneously with both hands.
Time: 5-7 minutes.
Description: The child was instructed to draws shapes and patterns with both hands simultaneously, enhancing fine motor skills and creativity.

- **Frenkel's Coordination Exercises (Lower Limb)**: These exercises were incorporated to enhance motor planning, sequencing, and proprioceptive feedback through slow, controlled limb movements.

1.Heel-To-Toe Walking:
Therapist Position: Standing beside or behind the child to provide support and guidance.
Child Position: Standing with feet together, then walking along a straight line or balance beam.
Repetitions: 5-10 steps, repeated 3-5 times.
2.Single-Leg Standing:
Therapist Position: Standing beside the child to provide support and balance assistance.
Child Position: Standing on one leg, with the other foot lifted off the ground.
Repetitions: Holding the position for 5-10 seconds, repeated 3-5 times on each leg.
3.Knee Lifts:
Therapist Position: Standing in front of the child to demonstrate and provide guidance.
Child Position: Standing with feet shoulder-width apart, lifting one knee up towards the chest.
Repetitions: 5-10 repetitions on each leg, repeated 3-5 times.
Toe Taps:
Therapist Position: Standing beside the child to provide support and guidance.
Child Position: Standing on one leg, tapping the toes of the other foot on a step or small block.
Repetitions: 5-10 repetitions on each leg, repeated 3-5 times.

- **Recall Memory Training**: Tasks included visual and auditory memory recall involving numbers, objects, and short patterns.

1.Motor Sequence Recall:
Therapist Position: Stand in front of the child and demonstrate a sequence of movements, such as clapping hands, tapping feet, or jumping jacks.
Child Position: Watch the therapist and imitate the sequence of movements.
Repetitions: Repeat the sequence 3-5 times, then ask the child to recall and perform the sequence without demonstration.
2.Action Recall:
Therapist Position: Perform a series of actions, such as touching different body parts (e.g., head, shoulders, knees, toes).
Child Position: Watch the therapist and imitate the actions.
Repetitions: Repeat the actions 3-5 times, then ask the child to recall and perform the actions without demonstration.
3.Object Manipulation Recall:
Therapist Position: Place objects (e.g., balls, blocks) in a specific sequence or pattern.
Child Position: Watch the therapist and manipulate the objects.
Repetitions: Repeat the sequence 3-5 times, then ask the child to recall and replicate the sequence.

- **Visuo-Motor Coordination Exercises**: Activities such as tracing shapes, copying figures, and tracking moving stimuli to improve spatial orientation and hand-eye coordination.

1.Ball Toss:
Therapist Position: Standing or sitting with the child, tossing a ball to the child.
Child Position: Catching the ball with both hands or one hand.
Repetitions: 5-10 repetitions, gradually increasing distance and difficulty.
2.Target Practice:
Therapist Position: Placing targets (e.g., cones, balloons) at varying distances.
Child Position: Throwing a ball or beanbag to hit the targets.
Repetitions: 5-10 repetitions, gradually increasing distance and difficulty.
3.Obstacle Course:
Therapist Position: Setting up an obstacle course with visual cues (e.g., cones, balance beams).
Child Position: Navigating the obstacle course, following visual cues.
Repetitions: 3-5 repetitions, gradually increasing complexity and difficulty.

Each session lasted approximately 45 minutes and was conducted individually. The therapist maintained a facilitatory position (either beside or behind the child) to provide support and verbal cues without interfering with task execution. A resting period of approximately two minutes was given between each exercise to avoid mental and physical fatigue.

Group B (control group) received motor skills exercise training such as,
Gross Motor Exercises
1. Running and Jumping (Using Obstacles)
Repetitions: 3 sets of 5-10 jumps
Duration: 10-15 minutes
Therapist Role: Provide support and guidance, ensure safety, and encourage proper technique
Child Position: Standing, facing obstacles (cones, hurdles, etc.)

2. Tandem Walking
   Repetitions: 3 sets of 10-15 steps
   Duration: 5-10 minutes
   Therapist Role: Provide support and guidance, ensure proper foot placement, and encourage balance and coordination
   Child Position: Standing, feet in tandem position (heel-to-toe)
3. Heel-Toe Walking
   Repetitions: 3 sets of 10-15 steps
   Duration: 5-10 minutes
   Therapist Role: Provide support and guidance, ensure proper foot placement, and encourage balance and coordination
   Child Position: Standing, feet in heel-to-toe position

4. Eye-Hand Coordination Exercise
   Repetitions: 3 sets of 10-15 throws/catches
   Duration: 5-10 minutes
   Therapist Role: Provide support and guidance, ensure proper throwing and catching technique, and encourage hand-eye coordination.

OUTCOME MEASURES

The Digit Span Test, a standardized and widely used neuropsychological tool to assess attention, immediate memory, and working memory capacity in children. The test consists of two components: Digit Span Forward and Digit Span Backward.

DIGIT SPAN FORWARD TASK:

In the Digit Span Forward task, children are required to listen to a series of numbers and repeat them in the same order. This part evaluates short-term auditory memory and attention span, as it primarily involves passive storage of information without the need for manipulation. It reflects the child's capacity to retain and reproduce simple verbal information over a short duration.

DIGIT SPAN BACKWARD TASK:

The Digit Span Backward task requires the child to recall the sequence of numbers in reverse order. This version is cognitively more demanding and serves as a measure of working memory, which includes the ability to temporarily store, manipulate, and retrieve information under a cognitive load. This function is especially important in academic tasks such as reading comprehension, mental arithmetic, and following multi-step instructions areas typically affected in children with learning difficulties. The test was chosen because of its high reliability, ease of administration, and sensitivity to changes following cognitive interventions. It has been extensively used in both clinical and educational settings to assess memory performance in children and adolescents [11].

TOOL RELIABILITY AND VALIDITY:

The Digit Span test is a reliable and valid measure of working memory. Research has shown that the test has good internal reliability, with coefficients ranging from 0.70 to 0.90 (Alloway et al., 2006). Test-retest reliability is also satisfactory, with coefficients between 0.50 and 0.83 (Wechsler, 1997). The test's validity has been established through correlations with other measures of working memory and cognitive functioning. For example, a study by Woods et al. (2011) demonstrated the test's construct validity by introducing new scoring metrics that improved measurement precision. Overall, the Digit Span test is a widely used and psychometrically sound assessment tool for evaluating verbal working memory capacity [35,36,37].

baseline scores for both Digit Span Forward and Digit Span Backward tests were obtained from all participants in both groups prior to the commencement of the intervention and also after three-month intervention period. The collected data were analyzed using SPSS Software, Version 24 to see the differences within each group and between the two groups. Paired t-tests were used to compare the pre- and post-intervention scores within each group to find out if there was any improvement in memory after the training. Unpaired t-tests were used to compare the post-intervention scores between Group A (who received cognitive training) and Group B (control group) to see if the training made a difference.

A p-value less than 0.05 was taken as statistically significant, meaning the improvement in memory was likely due to the training and not just by chance.

RESULTS

A total of 20 participants were enrolled in the study, with 10 children each in the intervention group (Group A) and the control group (Group B). Baseline scores for both Digit Span Forward and Backward tests were comparable between the two groups. Following the three-month intervention period, Group A showed a marked improvement in working memory scores. The mean increase in Digit Span Forward scores in Group A was 2.6 points, while the Digit Span Backward scores improved by 2.2 points, both of which were statistically significant ($p = 0.0001$) as presented in Table 1

Group A	Digit Span Forward	Digit Span Backward
	Mean (SD)	Mean (SD)
Pre-test	4.40(1.51)	3.20(0.92)
Post test	7.00(1.63)	5.40(1.43)
p value	0.0001	0.0001

Table 1: Pre and Post intervention values of Group A for Digit Span Forward & Backward test

In contrast, Group B demonstrated a modest increase of 0.5 points in the Digit Span Forward test, which was statistically significant (p = 0.015), but only a slight and statistically non-significant improvement of 0.5 points in the Digit Span Backward test (p = 0.2987), as seen in Table 2.

Table 2: Pre and Post intervention values of Group B for Digit Span Forward & Backward test

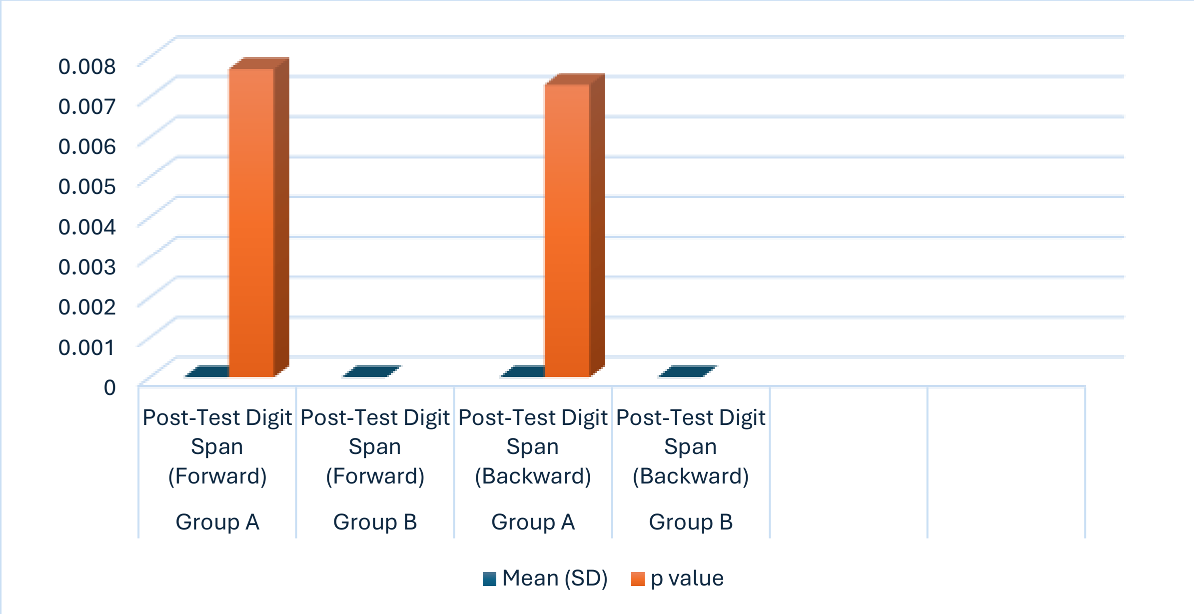
Group B	Digit Span Forward	Digit Span Backward
	Mean (SD)	Mean (SD)
Pre-test	4.50(1.08)	3.20(0.92)
Post test	5.00(1.33)	3.70(1.06)

A between-group comparison of post-test scores showed that Group A outperformed Group B significantly in both domains. Specifically, the mean post-test difference between the groups were 2.0 points for the Digit Span Forward test and 1.7 points for the Digit Span Backward test, with both results reaching statistical significance (p = 0.0077 and p = 0.0073 respectively), as shown in Table 3. These findings suggest a strong positive effect of the cognitive training program on the working memory abilities of children with learning difficulties.

Table 3: Comparison between the post-test values of Group A & B for Digit Span Forward & Backward test

	Group A	Group B	Group A	Group B
	Post-Test Digit Span (Forward)	**Post-Test Digit Span (Forward)**	**Post-Test Digit Span (Backward)**	**Post-Test Digit Span (Backward)**
Mean (SD)	7.00(1.63)	5.00(1.33)	5.40(1.43)	3.70(1.06)
p value	0.0077		0.0073	

GRAPHICAL REPRESENTATION



DISSCUSSION

The present study demonstrates that working memory (WM) training through structured cognitive exercises significantly enhances cognitive performance in children with learning disabilities (LD). These improvements were observed not only in the area of working memory itself but also in related skills such as attention, problem-solving, and academic functioning. This finding supports a growing body of evidence highlighting the importance of cognitive interventions in addressing the core deficits experienced by children with LD.

The findings of the present study are well supported by the review conducted by Priya Srikanth Rao et al. (2023), which emphasizes the key role of working memory in the learning process, especially among children with learning disabilities. The study highlights how working memory plays a major part in helping children register, store, and recall information all of which are essential for academic success. Our study adds to this by showing that specific cognitive exercises aimed at working memory can improve overall cognitive functioning in children with learning difficulties. This supports our finding that cognitive exercises not only improve memory but can also lead to better performance in daily school tasks [12]. Moreover, Wiest et al. (2022) examined the impact of cognitive training on school-aged children with ADHD and specific learning disorders (SLD), reporting enhancements in WM, attention, and impulsivity control. These findings suggest that cognitive training can be beneficial for children with co-occurring LD and ADHD, addressing multiple cognitive deficits simultaneously [13].

According to **Gray et al. (2012),** computerized working memory training not only improved WM in children with ADHD but also enhanced attention and reasoning skills [14]. Similarly, **Melby et al. (2013)** demonstrated that adaptive WM training produced gains in memory performance among children with poor working memory. Our study similar to these findings, suggesting that engaging and repetitive cognitive exercises such as sequencing, pattern recall, and spatial memory tasks can stimulate neuroplastic changes that contribute to improved memory capacity [15]. Our study found that working memory training helped improve memory and thinking skills in children with learning disabilities. This is similar to the results of a study by Peijnenborgh et al. (2015), who reviewed 13 research studies and found that such training improved both verbal and visual-spatial memory, as well as reading skills. Their review also showed that these improvements could last up to eight months after the training. They noted that children older than 10 years showed more improvement in verbal memory than younger children. Both studies showed that working memory training can be a helpful tool for children with learning difficulties [16].
The findings of Langdon et al (2012) study demonstrated that a combination of physical and cognitive activities, conducted at moderate levels, led to significant improvements in working memory and cognitive performance. This aligns with our approach, which involved targeted cognitive training aimed at improving working memory in children with learning disabilities. Both studies emphasize the importance of consistent, moderate interventions, and show that even without intense activity, structured cognitive exercises can lead to measurable improvements in cognitive function [17]. The results of our study align with the findings of Yiqing Wu et al. (2023), who examined the effectiveness of combined exercise and cognitive training (CECT) on working memory in older adults. Wu et al. found that CECT significantly improved working memory compared to no intervention, although the effects of CECT were similar to those of exercise or cognitive training alone. Similarly, our study demonstrated that targeted cognitive exercises effectively enhanced working memory in children with learning disabilities. Both studies

highlight the importance of structured, regular interventions to improve cognitive function, with our research focusing solely on cognitive training [18].

David Giofrè et al. (2016) highlighted that children with specific learning disorder (SLD) exhibited greater difficulty with the forward digit span task than the backward task, suggesting that their intellectual difficulties are more pronounced in tasks involving simpler, less cognitively demanding memory processing. Similarly, our study demonstrated that working memory performance in children with learning disabilities (LD) was significantly enhanced after engaging in structured cognitive exercises. These exercises were specifically designed to target and improve working memory deficits, including tasks like the digit span, which align with the challenges faced by children with SLD [19].

Brain Gym exercises offer a promising approach to improving cognitive function and learning in individuals with learning disabilities. By enhancing neuroplasticity, brain integration, and motor skills, these exercises can help compensate for neural differences and improve attentional abilities, processing speed, and overall cognitive function. Through mechanisms such as synaptic pruning, myelination, and sensory-motor integration, Brain Gym exercises promote neural reorganization and adaptation, allowing the brain to develop alternative pathways and strategies for learning. As a result, individuals with learning disabilities can experience improved academic performance, increased confidence, and enhanced learning strategies. By incorporating Brain Gym exercises into cognitive training programs, individuals with learning disabilities can potentially overcome specific challenges and achieve greater academic and personal success[20].

In conclusion, the findings from our study support the effectiveness of cognitive-based working memory training in children with learning disabilities. These results, when considered alongside previous research, suggest that cognitive training programs can play a crucial role in educational and therapeutic contexts. Future research should include long-term follow-up, larger sample sizes, and comparisons between different training modalities to determine the most effective approaches for sustained cognitive improvement.

CONCLUSION

In conclusion, the findings from our study support the effectiveness of cognitive-based working memory training in children with learning disabilities. These results, when considered alongside previous research, suggest that cognitive training programs can play a crucial role in educational and therapeutic contexts. Future research should include long-term follow-up, larger sample sizes, and comparisons between different training modalities to determine the most effective approaches for sustained cognitive improvement.

LIMITATION AND SUGGESSTIONS

In conclusion, the findings from our study support the effectiveness of cognitive-based working memory training in children with learning disabilities. These results, when considered alongside previous research, suggest that cognitive training programs can play a crucial role in educational and therapeutic contexts. Future research should include long-term follow-up, larger sample sizes, and comparisons between different training modalities to determine the most effective approaches for sustained cognitive improvement.

LIMITATIONS

- Limited sample size may not be representative of the larger population of children with learning disabilities.
- The study may only focus on specific working memory interventions, which may not be generalizable to other interventions or strategies.
- The study may only examine short-term effects of the interventions, without considering long-term outcomes.

SUGGESTIONS

- Conduct the study with a larger sample size to increase generalizability and representation of the population.
- Include a variety of working memory interventions to examine their effectiveness and identify the most beneficial strategies.
- Conduct long-term follow-up assessments to examine the sustainability of the effects of the interventions.
- Consider an individualized approach to the interventions, tailoring them to each child's specific needs and abilities.

REFERENCES

1. Scaria LM, Bhaskaran D, George B. Prevalence of Specific Learning Disorders (SLD) Among Children in India: A Systematic Review and Meta-Analysis. Indian J Psychol Med. 2023;45(3). Available from: https://doi.org/10.1177/02537176221100128

2. Plomin R, Kovas Y, Haworth CM, Price TS, Dale PS, Petrill SA. Genetics of learning abilities and disabilities: recent developments from the UK and possible directions for research in China. Behav Genet. 2010 May;40(3):297-305. doi: 10.1007/s10519-010-9355z.
3. Schlaggar BL, McCandliss BD. Development of neural systems for reading. Annu Rev Neurosci. 2007;30:475-503. doi: 10.1146/annurev.neuro.28.061604.135645.
4. Peterson RL, Pennington BF. Developmental dyslexia. Lancet. 2012 May 26;379(9830):1997-2007. doi: 10.1016/S0140-6736(12)60198-6.
5. American Psychiatric Association. Diagnostic and Statistical Manual of Mental Disorders: DSM-5®. 5th ed. Washington, DC: American Psychiatric Publishing; 2013.
6. Lyon GR, Shaywitz SE, Shaywitz BA. A definition of dyslexia. Ann Dyslexia. 2003;53(1):1–14.
7. U.S. Department of Health and Human Services. National Health Interview Survey, 2019. Centers for Disease Control and Prevention.
8. Alloway TP. Working memory, reading, and mathematical skills in children with developmental coordination disorder. J Exp Child Psychol. 2007 Jan;96(1):20-36. doi: 10.1016/j.jecp.2006.07.002.
9. Peijnenborgh JC, Hurks PP, Aldenkamp AP, Vles JS, Hendriksen JG. Efficacy of working memory training in children and adolescents with learning disabilities: A review study and meta-analysis. Neuropsychol Rehabil. 2016;26(5-6):645–672. doi: 10.1080/09602011.2015.1026356.
10. Zakopoulou V, Sarris D, Zaragkas C, Tsampalas E, Vergou M. Working memory and learning difficulties: coexistence or a strong relationship? Eur J Spec Educ Res. 2019 Sep 30.
11. Giofrè D, Stoppa E, Ferioli P, Pezzuti L, Cornoldi C. Forward and backward digit span difficulties in children with specific learning disorder. J Clin Exp Neuropsychol. 2016;38(4):478-86. doi: 10.1080/13803395.2015.1125454.
12. Rao PS, Pandey MK, Mishra P, Deshmukh S, Jahan M, Manohar J S. Is Training Working Memory in Children with Learning Disabilities a Viable Solution? A Systematic Review. Annals of Neurosciences. 2023;31(2):124-131. doi:10.1177/09727531231198639
13. Wiest, G. M., Rosales, K. P., Looney, L., Wong, E. H., & Wiest, D. J. (2022). Utilizing Cognitive Training to Improve Working Memory, Attention, and Impulsivity in School-Aged Children with ADHD and SLD. Brain Sciences, 12(2), 141. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC8870288/
14. Melby-Lervåg, M., & Hulme, C. (2013). Efficacy of working memory training in children and adolescents with learning disabilities: A review study and meta-analysis. Frontiers in Psychology, 4, 289. https://pubmed.ncbi.nlm.nih.gov/25886202/
15. Gray, S. A., Chaban, P., Martinussen, R., Goldberg, R., Gotlieb, H., Kronitz, R., ... & Tannock, R. (2012). Effects of a computerized working memory training program on working memory, attention, and academics in adolescents with severe LD and comorbid ADHD: a randomized controlled trial. Journal of Child Psychology and Psychiatry, 53(12), 1277-1284. https://acamh.onlinelibrary.wiley.com/doi/full/10.1111/j.1469-7610.2012.02592.x
16. Peijnenborgh, J. C. A. W., Hurks, P. M., Aldenkamp, A. P., Vles, J. S. H., & Hendriksen, J. G. M. (2015). Efficacy of working memory training in children and adolescents with learning disabilities: A review study and meta-analysis. Neuropsychological Rehabilitation, 26(5–6), 645–672. https://doi.org/10.1080/09602011.2015.1026356
17. Langdon KD, Corbett D. Improved Working Memory Following Novel Combinations of Physical and Cognitive Activity. Neurorehabilitation and Neural Repair. 2011;26(5):523-532. doi:10.1177/1545968311425919
18. Wu, Y., Zang, M., Wang, B., & Guo, W. (2023). Does the combination of exercise and cognitive training improve working memory in older adults? A systematic review and meta-analysis. PeerJ, 11, e15108. https://doi.org/10.7717/peerj.15108
Giofrè, D., Stoppa, E., Ferioli, P., Pezzuti, L., & Cornoldi, C. (2016). Forward and backward digit span difficulties in children with specific learning disorder. Journal of Clinical and
19. Agbo, CJ, & Omekwu, CO (2022). Brain gym as a tool for improving the academic performance of secondary school students in Nigeria. European Journal of Education Studies, 9(1), 58-73.
20. Ramaswamy, S., Jayachandran, S., & Kandasamy, P. (2022). Prevalence of specific learning disorders in India: A systematic review and meta-analysis. Industrial Psychiatry Journal, 31(Suppl S2), 386–391.
21. Chacko, D., & Vidhukumar, K. (2020). Prevalence of specific learning disorder among school-going children in Ernakulam district, Kerala, India: A cross-sectional study. Indian Journal of Psychological Medicine, 42(4), 349–354.
22. Sharma, N., Gupta, S., & Sumit, M. (2011). Specific learning disabilities: Screening and remediation. Indian Journal of Pediatrics, 78(7), 820–822.
23. Carretti, B., Giofrè, D., Toffalini, E., Cornoldi, C., Pastore, M., & Lanfranchi, S. (2022). Structure of working memory in children from 3 to 8 years old. Developmental Psychology, 58(9), 1687–1701.
24. Giofrè, D., Mammarella, I. C., & Cornoldi, C. (2021). The structure of working memory from a developmental perspective: Evidence from a meta-analysis. British Journal of Developmental Psychology, 39(3), 354–370.
25. Melby-Lervåg, M., & Hulme, C. (2013). Is working memory training effective? A meta-analytic review. Developmental Psychology, 49(2), 270–291.

26. Maehler, C., Schuchardt, K., & Hasselhorn, M. (2015). Efficacy of working memory training in children and adolescents with learning disabilities: A meta-analytic review. Frontiers in Psychology, 6, 1138.
27. Sala, G., & Gobet, F. (2017). Working memory training in typically developing children: A meta-analysis of the available evidence. Developmental Psychology, 53(4), 671–685.
28. Peng, P., & Fuchs, D. (2016). A Meta-Analysis of Working Memory Deficits in Children with Learning Difficulties. Journal of Learning Disabilities, 49(4), 411–427.
29. Peijnenborgh, J. C., Hurks, P. P., Aldenkamp, A. P., & Vles, J. S. (2016). Working memory training in children with learning disabilities: A meta-analysis of randomized controlled trials. Neuropsychology Review, 26(1), 18–31.
30. Orsolini, M., Amore, M., & Brugnoli, R. (2018). Effects of verbal working memory training on problem-solving in children with mild intellectual disabilities. Psychological Reports, 121(6), 1069–1085.
31. Ramezani, M., Taheri, S., & Hosseini, M. (2021). Impact of verbal working memory intervention on reading performance in students with specific learning disabilities. Behavioral Sciences, 11(3), 356.
32. Holmes, J., Gathercole, S. E., & Dunning, D. L. (2009). Adaptive training leads to sustained enhancement of poor working memory in children. Developmental Science, 12(4), F9-F15.
33. Klingberg, T., Forssberg, H., & Westerberg, H. (2005). Training of working memory in children with ADHD. Journal of Clinical and Experimental Neuropsychology, 27(6), 781-791. https://doi.org/10.1080/13803390490509574 1. Gathercole, S. E., & Pickering, S. J. (2000). Working memory deficits in children with learning difficulties: A review. Journal of Child Psychology and Psychiatry, 41(6), 769-784.
34. Alloway, T. P., Gathercole, S. E., & Pickering, S. J. (2006). Verbal and visuospatial short-term and working memory in children: Are they separable? Child Development, 77(4), 1069-1086.
35. Holmes, J., Gathercole, S. E., & Dunning, D. L. (2009). Adaptive training leads to sustained enhancement of poor working memory in children. Developmental Science, 12(4), 668-675.
36. Alloway, T. P., Gathercole, S. E., & Pickering, S. J. (2013). Working memory and the special educational needs of children with reading disabilities. Journal of Child Psychology and Psychiatry, 54(3), 274-283.
37. Alloway, T. P., Gathercole, S. E., Adams, A., Willis, C., Eaglen, R., & Lamont, E. (2015). Working memory and the developing brain. Journal of Child Psychology and Psychiatry, 56(3), 274-287.
38. Cuesta-Vargas AI, Paz-Lourido B, Rodriguez A. Physical fitness profile in adults with intellectual disabilities: differences between levels of sport practice. Research in Developmental Disabilities. 2011;32(2):788-94.
39. Brunoni, A. R., Lopes, M., and Fregni, F. (2008). A systematic review and meta- analysis of clinical studies on major depression and BDNF levels: implications for the role of neuroplasticity in depression. Int. J. Neuropsychopharmacol. 11, 1169–1180. doi: 10.1017/S1461145708009309