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Effectiveness of Working Memory Training on Executive Functions and Cognitive Flexibility in Students with Specific Learning Disorder

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ABSTRACT

The present study aimed to determine the effectiveness of working memory training on executive functions and cognitive flexibility in students with specific learning disorder. Methodologically, this study was quasi-experimental and employed a pretest–posttest design with a control group. The statistical population included all children diagnosed with specific learning disorders in Ardabil City during the second semester of the 2023–2024 academic year. The research sample consisted of 45 children with specific learning disorder, who were then randomly assigned to two groups of 15 participants each (experimental group and control group). The experimental group received group-based working memory training over 12 sessions of 60 minutes each, whereas the control group did not receive any therapeutic intervention during the study period. Data collection instruments included the Learning Problems Questionnaire developed by Wilcutt et al. (2011), the Behavior Rating Inventory of Executive Function developed by Gioia et al. (2000), and the Wisconsin Card Sorting Test developed by Grant and Berg (1948). The obtained data were analyzed using repeated-measures analysis of variance. The results indicated that working memory training had a significant effect on executive functions and cognitive flexibility in students with specific learning disorder. Accordingly, it can be concluded that working memory training can be used to improve executive functions and cognitive flexibility in students with specific learning disorder.

Keywords: *Working memory training; executive functions; cognitive flexibility; specific learning disorder.*

1. Introduction

Specific Learning Disorder (SLD) is one of the most prevalent neurodevelopmental disorders of childhood and adolescence, characterized by persistent difficulties in academic skills such as reading, writing, and mathematics that are substantially below age expectations and interfere with academic achievement and daily functioning (American Psychiatric, 2013, 2015). These difficulties cannot be explained by intellectual disability, uncorrected sensory impairments, or inadequate educational opportunities, and they often persist across the lifespan, imposing long-term educational, psychological, and social challenges (Ahadi & Kakavand, 2018; Alizadeh, 2018). Contemporary diagnostic frameworks emphasize that SLD is not limited to isolated academic weaknesses but is frequently associated with broader cognitive and executive dysfunctions that undermine learning efficiency and adaptability (Swanson & Howard, 2005; Swanson & Jerman, 2007).

Among the cognitive mechanisms implicated in SLD, executive functions have received particular attention. Executive functions refer to a set of higher-order cognitive processes, including inhibition, cognitive flexibility, planning, monitoring, and working memory, that regulate goal-directed behavior and adaptive problem solving (Kirk et al., 2015; Thorell et al., 2009). Deficits in executive functions are consistently reported in children with SLD and are considered a major contributor to their academic underachievement and difficulties in classroom functioning (Amani et al., 2017; Magalhães et al., 2020). Research indicates that impairments in executive functions not only affect academic performance directly but also limit the child's capacity to benefit from instructional interventions, thereby perpetuating learning difficulties over time (Krause, 2015; Maehler & Schuchardt, 2016).

Working memory, as a core component of executive functioning, plays a critical role in learning and academic achievement. Working memory refers to the capacity to temporarily store and manipulate information necessary for complex cognitive tasks such as comprehension, reasoning, and learning (Alloway, 2007; Aspen & Anne, 2022). A substantial body of evidence demonstrates that children with SLD exhibit marked deficits in working memory compared to their typically developing peers, particularly in tasks requiring simultaneous processing and storage of information (Kartini & Susan, 2013; Maehler & Schuchardt, 2016). These deficits have been linked to difficulties in reading comprehension, mathematical problem solving, and written expression, highlighting working memory as a central cognitive vulnerability in SLD (Magalhães et al., 2020; Swanson & Jerman, 2007).

Cognitive flexibility is another executive function that has been increasingly recognized as essential for adaptive learning. Cognitive flexibility refers to the ability to shift between tasks, strategies, or mental sets in response to changing demands or feedback (Dennis & Vander Wal, 2010; Jacques & Zelazo, 2005). Children with SLD often demonstrate rigid cognitive styles, perseverative responding, and difficulty adapting to new rules or problem-solving strategies, which further compromise academic performance and classroom behavior (Amani et al., 2017; Krause, 2015). Empirical studies using neuropsychological measures such as the Wisconsin Card Sorting Test consistently show reduced cognitive flexibility and increased perseverative errors in this population (Krause, 2015; Kunlin et al., 2017).

Theoretical and empirical models suggest that working memory and cognitive flexibility are closely interconnected processes. Effective cognitive flexibility depends on the capacity to maintain task rules, update information, and inhibit irrelevant responses, all of which rely heavily on working memory resources (Aspen & Anne, 2022; Jongbloed-Pereboom et al., 2019). Neurocognitive evidence further indicates overlapping neural networks, particularly within the prefrontal cortex, that support both working memory and flexible control of behavior (Horowitz-Kraus, 2015; Kesler et al., 2018). Consequently, interventions that target working memory may produce generalized benefits for broader executive functions, including cognitive flexibility.

In recent years, cognitive and executive function training programs have emerged as promising approaches for improving learning-related cognitive deficits in children with SLD. Working memory training programs typically involve structured, repetitive tasks designed to progressively challenge memory capacity and executive control processes (Abedi & Malekpour, 2010; Kamiabi et al., 2014). Several studies have reported positive effects of working memory training on attention, executive functioning, and academic-related skills in children with learning disabilities (Dehghani & Moradi, 2020; Zarei et al., 2020). These findings align with broader evidence supporting the plasticity of executive functions and the potential for targeted cognitive interventions to induce meaningful improvements (Kirk et al., 2015; Thorell et al., 2009).

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Nevertheless, the effectiveness of working memory training remains a topic of ongoing debate. While some studies report significant near-transfer and far-transfer effects, others have found limited or inconsistent outcomes, particularly with respect to generalization beyond trained tasks (Pumaccahua et al., 2017; Veloso et al., 2020). Methodological differences, such as variations in training duration, task complexity, participant characteristics, and outcome measures, may partly account for these mixed findings (Guo & Keles, 2025; Veloso et al., 2020). Therefore, there is a clear need for rigorously designed studies that examine the impact of working memory training on multiple executive domains, including cognitive flexibility, using controlled experimental designs.

Recent developments in technology-enhanced and adaptive cognitive interventions have further renewed interest in executive function training for individuals with learning disabilities. Advances in computerized training, artificial intelligence–based adaptive systems, and inclusive educational technologies have expanded the potential reach and personalization of cognitive rehabilitation programs (Gadekallu et al., 2025; Shao et al., 2025). These innovations underscore the importance of grounding intervention research in solid cognitive theory while also addressing practical considerations related to accessibility and sustainability in educational settings.

Within the Iranian and broader international context, several studies have demonstrated the benefits of cognitive and working memory training for children with learning disabilities, particularly in improving attention, planning, and academic-related skills (Abedi & Malekpour, 2010; Kamiabi et al., 2014; Zarei et al., 2020). However, fewer studies have systematically examined the combined effects of working memory training on executive functions and cognitive flexibility simultaneously, especially using follow-up assessments to evaluate the stability of intervention effects. Given the central role of executive functions in academic success and adaptive functioning, addressing this gap is of both theoretical and practical significance.

Furthermore, cognitive flexibility is increasingly recognized not only as a cognitive skill but also as a contributor to emotional regulation, social adaptation, and resilience in educational contexts (Baron & Byrn, 2004; Gan et al., 2004). Difficulties in cognitive flexibility may exacerbate frustration, anxiety, and maladaptive coping strategies in students with SLD, thereby compounding their learning challenges (Jafarzadeh Dashbalagh et al., 2019; Yovel et al., 2005). Interventions that enhance cognitive flexibility may therefore yield broader psychosocial benefits beyond academic performance.

Considering the high prevalence of SLD, its strong association with executive dysfunction, and the promising yet inconclusive evidence regarding working memory training, further empirical investigation is warranted. Specifically, studies that employ structured working memory training protocols, assess multiple components of executive functions and cognitive flexibility, and include follow-up measurements can provide more robust evidence regarding the effectiveness and durability of such interventions. Addressing these issues is particularly important for informing evidence-based educational and clinical practices aimed at supporting students with SLD.

Accordingly, the present study was designed to examine the effectiveness of working memory training on executive functions and cognitive flexibility in students with specific learning disorder.

2. Methods and Materials

2.1. Study Design and Participants

The present study is applied in terms of research objective and, in terms of methodology, constitutes a quasi-experimental study with a pretest–posttest design, including a control group and a follow-up period. In this study, the experimental group received working memory training, whereas the control group proceeded without undergoing any training program. Subsequently, both groups were evaluated simultaneously with respect to the research variables. The statistical population of the present study included all children diagnosed with specific learning disorders in Ardabil City during the second semester of the 2023–2024 academic year. From this population, the research sample consisted of 45 children with specific learning disorder who had referred to special learning difficulties centers in Ardabil City (public and private centers for the treatment of learning disorders). Moreover, to ensure greater precision in sample selection, the Colorado Learning Difficulties Questionnaire was used to achieve a more accurate diagnosis of learning disorders in the target population, and participants were selected based on high obtained scores and the study inclusion criteria. These individuals were then randomly assigned to two experimental groups of 15 participants and one control group of 15 participants. In experimental research, a minimum sample size of 15 participants per group has been

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recommended (Delavar, 2013). Additionally, given that random sampling was not feasible in this study, convenience sampling was employed to select the research sample. Inclusion criteria included completion of the parental informed consent form for participation in the training program, enrollment in the fourth, fifth, or sixth grade of elementary school, obtaining a high score on the learning difficulties questionnaire, and absence of other psychological disorders. Exclusion criteria included unwillingness to continue participation during the program, absence from two consecutive training sessions, and incomplete or invalid questionnaires.

2.2. Measures

Colorado Learning Difficulties Questionnaire: This questionnaire was developed by Wilcutt et al. (2011) and conceptualizes learning difficulties as comprising five core factors: reading, mathematics, social cognition, social anxiety, and spatial functioning, which contribute to learning problems. The questionnaire consists of 20 items and is completed by parents of students. Responses are rated on a 5-point Likert scale ranging from “never” (1) to “always” (5). The reliability of the Learning Difficulties Questionnaire and its components was examined by the developers using internal consistency and test–retest methods, yielding acceptable values. Discriminant validity and construct validity of the questionnaire have been reported as satisfactory. In addition, convergent validity of the questionnaire components with standardized academic achievement questionnaires was reported as follows: reading (r = .64), mathematics (r = .44), social cognition (r = .64), social anxiety (r = .46), and spatial functioning (r = .30) (Wilcutt et al., 2011). In the study by Hajloo and Rezaei Sharif (2011), internal consistency and test–retest reliability methods were used to evaluate the reliability of the Colorado Learning Difficulties Questionnaire. Cronbach’s alpha coefficients for the total questionnaire and its subscales were reported as .90, .88, .83, .85, .72, and .71, respectively. Content validity of the Colorado Learning Difficulties Questionnaire was examined and confirmed by the questionnaire developers. In the present study, the accuracy and clarity of the translation were also confirmed through forward translation from English to Persian and backward translation from Persian to English. To assess discriminant validity, two normal and clinical groups were compared using an independent samples t test. Construct validity was examined through correlations between the questionnaire and its subscales as well as exploratory and confirmatory factor analyses. High correlations were observed between the total score of the Colorado Learning Difficulties Questionnaire and its five subscales, including reading (r = .81), social cognition (r = .78), social anxiety (r = .76), spatial difficulties (r = .70), and mathematics (r = .60). The significance of these relationships indicates that the Colorado Learning Difficulties Questionnaire possesses satisfactory construct validity.

Behavior Rating Inventory of Executive Function (BRIEF): The Behavior Rating Inventory of Executive Function was developed by Gioia et al. (2000). This instrument includes parent and teacher forms and consists of 86 items, which are rated by parents on a scale from 1 to 3 (“never,” “sometimes,” and “often”), based on the child’s behavior in home or school settings. It is designed to provide a behavioral interpretation of executive functioning in children aged 5 to 18 years (Gioia et al., 2000). Completion time for this questionnaire ranges from 10 to 15 minutes, and items are scored using a Likert-type scale. Each item corresponds to one of the questionnaire subscales, which are divided into two main domains: behavioral regulation skills and metacognitive skills. Behavioral regulation skills include inhibition, attention shifting, and emotional control, whereas metacognitive skills include planning, organization of materials, monitoring/control, working memory, and initiation. The reliability coefficients reported by the developers for clinical samples using the parent form range from .82 to .98, and from .80 to .97 when used in normative samples. In Iran, content validity assessment of this scale indicated that nearly all questionnaire items obtained content validity index scores above .79 (minimum = .80, maximum = 1.00). Test–retest reliability coefficients for the subscales were reported as .90 for inhibition, .81 for shifting, .91 for emotional control, .80 for initiation, .71 for working memory, .81 for planning, .79 for organization of materials, .78 for monitoring/control, .90 for the Behavioral Regulation Index, .87 for the Metacognition Index, and .89 for the total executive function score. Internal consistency coefficients ranged from .87 to .94, indicating high internal consistency across all subscales.

Wisconsin Card Sorting Test (WCST): The Wisconsin Card Sorting Test was developed by Grant and Berg in 1948. This test has been formally used to assess abstract reasoning and cognitive flexibility. Participants are presented with a set of 64 cards depicting one to four symbols (red triangles, green stars, yellow crosses, and blue circles), with no two cards being identical. The task requires participants to infer

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the sorting principle used by the examiner and place the cards accordingly. The sorting principles include color, shape, and number of symbols, which are changed by the examiner without informing the participant. When a participant correctly sorts 10 consecutive cards according to one principle, the examiner changes the rule, and the participant must infer the new principle based on feedback ("correct" or "incorrect"). The test continues until the participant completes six categories or explicitly identifies the underlying principle change. Typically, the test is discontinued if 30 to 40 cards are sorted incorrectly and the participant appears unwilling or unable to understand the task. The WCST can be scored using several methods, with the most common being the number of categories achieved and perseverative errors. Perseverative errors reflect difficulties in concept formation, utilization of feedback, and perceptual flexibility. The number of correct responses refers to the total number of correctly sorted cards (maximum score of 60). The validity of this test has been reported to be approximately .86. Spreen and Strauss (1991) reported inter-rater reliability of 93%, and Axler et al. (1992) reported reliability coefficients of .90, with agreement rates of 94%. Inter-rater reliability has also been reported to be excellent and above .83. In a study by Sarmad et al. (1998), reliability coefficients for the number of categories and perseverative errors were reported as .73 and .74, respectively.

2.3. Intervention

The intervention used in this study consisted of a structured working memory training program aimed at cognitive rehabilitation of memory and learning in students with specific learning disorder. This intervention package was implemented based on the training guidelines of the Denn educational program (Denn, 2008), adapted and structured by Abedi (2010), and was delivered in 12 group-based sessions over a six-week period, with each session lasting 60 minutes. Following an initial orientation session that introduced group rules, established rapport among participants, clarified session goals, and emphasized the role of working memory in learning performance for both students and parents, the program progressed through sequential, skill-focused sessions. The sessions included training in auditory working memory through activities such as following and recalling verbal instructions, repeating sentences, remembering short sequences of numbers, words, and simple poems, and sequencing events; visual working memory through tasks involving object concealment, identification of missing items, recall of visual stimuli and faces, and repetition of visual patterns; combined auditory–visual memory exercises with increased practice intensity; image-based games requiring recall of colors and spatial directions after short delays; execution of multiple simultaneous instructions to enhance updating and monitoring; motor working memory through imitation and reconstruction of movements observed in short video clips; recognition memory using delayed identification of pictures depicting children, animals, fruits, and objects; recall memory through retelling short stories read aloud; long-term memory training via detailed recall of events from the previous 24 hours; and learning lists involving memorization and recall of predefined word lists and sentence repetition. The final session focused on consolidation, review, and integration of all previously practiced working memory exercises to reinforce learning and skill transfer (Denn, 2008; Abedi, 2010).

2.4. Data Analysis

Data were analyzed in two sections: descriptive and inferential. In the descriptive section, indices such as mean and standard deviation were used. In the inferential statistics section, the Kolmogorov–Smirnov test was applied to examine the normality of data distribution. Repeated-measures analysis of variance and Bonferroni post hoc tests were conducted to compare the effectiveness of the two interventions, using SPSS version 26.

3. Findings and Results

Initially, the demographic characteristics of the research sample were reported in Table 4-1, indicating that the total study sample consisted of 45 students with specific learning disorder, of whom 23 were boys (51.11%) and 22 were girls (48.89%). The highest frequency was observed in the age range of 12 years, with 12 students (26.67%). Additionally, 11 students (24.24%) were 9 years old, 11 students (24.24%) were 10 years old, and 11 students (24.24%) were 11 years old. The mean age of the total sample was reported as 10.45 years with a standard deviation of 2.33. With respect to grade level, 15 students (33.34%) were enrolled in the fourth grade, 15 students (33.34%) in the fifth grade, and 15 students (33.34%) in the sixth grade. Regarding the type of learning disorder, 11 students (24.24%) had a reading disorder, 11 students (24.24%) had a writing disorder, 12 students (26.67%) had a mathematics disorder, and 11

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students (24.24%) had a mixed type of learning disorder. The socioeconomic status of the sample included 17 students (37.78%) with a moderate status, 13 students (28.89%) with a good status, and 15 students (33.34%) with a low status. In terms of parental education among students in the sample, the highest frequency was observed for diploma and associate degree levels with 19 parents (42.22%), followed by bachelor's degree with 18 parents (40.00%), and finally master's degree and higher with 8 parents (17.78%).

Table 1

Descriptive Statistics (Mean and Standard Deviation) for Executive Functions and Cognitive Flexibility in the Working Memory Training and Control Groups Across Measurement Stages

Variable	Component	Stage	Control Group (n = 15) M	Control Group SD	Working Memory Group (n = 15) M	Working Memory Group SD
Executive Functions	Behavioral Regulation Skills	Pretest	31.87	6.99	30.71	5.40
		Posttest	32.00	6.89	38.67	7.87
		Follow-up	31.27	6.97	37.10	6.42
Executive Functions	Metacognitive Skills	Pretest	49.80	6.54	54.93	8.91
		Posttest	50.67	5.58	67.07	4.36
		Follow-up	49.93	5.55	66.40	4.68
Executive Functions	Total Score	Pretest	80.13	12.33	84.60	13.75
		Posttest	81.60	11.53	101.67	9.26
		Follow-up	81.47	11.03	100.40	10.99
Cognitive Flexibility	Number of Categories	Pretest	3.55	2.21	2.55	1.40
		Posttest	3.37	1.32	5.35	1.87
		Follow-up	3.02	1.97	5.10	0.88
Cognitive Flexibility	Perseverative Errors	Pretest	6.98	1.54	8.93	2.91
		Posttest	6.22	1.09	3.27	1.36
		Follow-up	5.93	1.22	3.55	1.68
Cognitive Flexibility	Total Score	Pretest	17.13	4.33	17.59	4.12
		Posttest	17.60	4.53	31.67	8.23
		Follow-up	16.47	4.03	32.11	8.99

As shown in Table 1, the working memory training and control groups demonstrated relatively comparable mean scores at the pretest stage across all components of executive functions and cognitive flexibility. Following the intervention, the working memory training group exhibited notable improvements at the posttest stage in behavioral regulation skills, metacognitive skills, and total executive function scores, and these gains were largely maintained at the follow-up assessment. In contrast, the control group showed minimal changes across all three measurement stages. A similar pattern was observed for cognitive flexibility outcomes. Specifically, the working memory training group demonstrated an increase in the number of achieved categories, a reduction in perseverative errors, and a substantial rise in total cognitive flexibility scores at posttest and follow-up, whereas the control group displayed only slight fluctuations with no meaningful improvement over time. These descriptive findings suggest a positive trend in executive functions and cognitive flexibility associated with working memory training.

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Table 2

Results of Repeated-Measures Analysis of Variance for Executive Functions and Cognitive Flexibility

Variable	Component	Effect	df (Effect)	df (Error)	F	Partial η²
Executive Functions	Behavioral Regulation Skills	Time (R)	2	42	13.67*	.136
		Group (C)	1	42	3.99*	.228
		Time × Group (C × R)	2	42	45.13	.228
Executive Functions	Metacognitive Skills	Time (R)	2	42	14.26*	.218
		Group (C)	1	42	4.47*	.232
		Time × Group (C × R)	2	42	45.09	.218
Executive Functions	Total Score	Time (R)	2	42	12.26*	.253
		Group (C)	1	42	5.31*	.378
		Time × Group (C × R)	2	42	45.03	.253
Cognitive Flexibility	Number of Categories	Time (R)	2	42	19.12**	.313
		Group (C)	1	42	4.34*	.271
		Time × Group (C × R)	2	42	45.48	.313
Cognitive Flexibility	Perseverative Errors	Time (R)	2	42	6.60**	.136
		Group (C)	1	42	5.25**	.328
		Time × Group (C × R)	2	42	45.61	.136
Cognitive Flexibility	Total Score	Time (R)	2	42	11.73**	.218
		Group (C)	1	42	10.60**	.378
		Time × Group (C × R)	2	42	45.19	.218

As shown in Table 2, the repeated-measures analyses revealed significant main effects of time and group, as well as significant time × group interaction effects for all components of executive functions and cognitive flexibility. For executive functions, significant time effects indicated changes across pretest, posttest, and follow-up in behavioral regulation skills, metacognitive skills, and total executive function scores. Significant group effects demonstrated overall differences between the working memory training and control groups, and the significant interaction effects indicate that changes over time differed by group, favoring the working memory training group. Similarly, for cognitive flexibility, significant time, group, and time × group interaction effects were observed for number of categories, perseverative errors, and total cognitive flexibility scores. The partial eta-squared values ranged from small to large, indicating meaningful effect sizes, particularly for the interaction effects, which suggests that working memory training produced statistically significant and practically meaningful improvements in executive functions and cognitive flexibility over time compared with the control condition.

Table 3

Bonferroni Post Hoc Test Results for Between-Group Comparisons of Executive Functions and Cognitive Flexibility

Variable	Component	Group Comparison	Mean Difference (MD)	Standard Error	p
Executive Functions	Behavioral Regulation Skills	Working Memory Training – Control	1.47	0.80	.047
Executive Functions	Metacognitive Skills	Working Memory Training – Control	8.07*	0.87	.020
Executive Functions	Total Executive Functions	Working Memory Training – Control	8.07*	0.87	.020
Cognitive Flexibility	Number of Categories	Working Memory Training – Control	−6.27*	0.13	.040
Cognitive Flexibility	Perseverative Errors	Working Memory Training – Control	−6.73**	0.87	.003
Cognitive Flexibility	Total Cognitive Flexibility	Working Memory Training – Control	1.60*	0.53	.010

As presented in Table 3, the Bonferroni post hoc comparisons revealed statistically significant differences between the working memory training and control groups across most components of executive functions and cognitive flexibility. Specifically, students in the working memory training group demonstrated significantly higher scores in behavioral regulation skills, metacognitive skills, and total executive functions compared with the control group, indicating superior executive functioning following the intervention. In the domain of cognitive flexibility, the working memory training group achieved a significantly greater number of categories and exhibited significantly fewer perseverative errors than the control group, reflecting enhanced cognitive flexibility and reduced cognitive rigidity. Additionally, the total cognitive flexibility score was significantly higher in the working memory training

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group. These findings indicate that working memory training led to meaningful and statistically significant improvements in both executive functions and cognitive flexibility compared with the control condition.

Table 4

Paired-Samples t Test Results for Posttest and Follow-Up Comparisons in the Working Memory Training Group (n = 15)

Variable	Component	Measurement Stage	M	SD	Mean Difference	SD of Differences	SE	t(14)	p
Executive Functions	Behavioral Regulation Skills	Posttest	38.67	7.87	−1.57	1.43	0.47	0.141	.890
		Follow-up	37.10	6.42					
Executive Functions	Metacognitive Skills	Posttest	67.07	4.36	−0.33	0.32	0.49	1.633	.125
		Follow-up	66.40	4.68					
Executive Functions	Total Executive Functions	Posttest	101.67	9.26	1.73	1.83	0.47	0.125	.890
		Follow-up	100.40	10.99					
Cognitive Flexibility	Number of Categories	Posttest	5.35	1.87	−0.25	1.07	0.68	1.079	.299
		Follow-up	5.10	0.88					
Cognitive Flexibility	Perseverative Errors	Posttest	3.27	1.36	0.28	0.32	0.59	−0.564	.582
		Follow-up	3.55	1.68					
Cognitive Flexibility	Total Cognitive Flexibility	Posttest	31.67	8.23	−0.56	0.76	0.21	1.293	.217
		Follow-up	32.11	8.99					

As shown in Table 4, paired-samples t tests were conducted to examine the stability of intervention effects from posttest to follow-up within the working memory training group. The results indicated that none of the differences between posttest and follow-up scores for behavioral regulation skills, metacognitive skills, or total executive functions were statistically significant ($p > .05$), suggesting that the gains achieved following the intervention were maintained over time. Similarly, no significant differences were observed between posttest and follow-up scores for the number of categories, perseverative errors, or total cognitive flexibility ($p > .05$). These findings indicate that the improvements in executive functions and cognitive flexibility observed after working memory training remained stable during the follow-up period, supporting the durability of the intervention effects.

4. Discussion

The findings of the present study demonstrated that working memory training led to significant improvements in executive functions and cognitive flexibility among students with specific learning disorder, and that these gains were maintained at follow-up. Specifically, the repeated-measures analyses indicated significant time, group, and time × group interaction effects for behavioral regulation skills, metacognitive skills, total executive functions, and indices of cognitive flexibility. These results suggest that the observed improvements cannot be attributed to natural maturation or repeated testing effects alone, but rather reflect the specific impact of the working memory training program. This pattern of findings is consistent with theoretical models that conceptualize working memory as a core mechanism underlying executive control processes and adaptive cognitive functioning (Alloway, 2007; Aspen & Anne, 2022). By systematically engaging children in tasks that required the storage, updating, and manipulation of information, the intervention appears to have strengthened executive control capacities that are essential for goal-directed behavior and flexible problem solving.

The significant improvement observed in behavioral regulation skills following the intervention is particularly noteworthy. Behavioral regulation, which includes inhibitory control, emotional regulation, and attentional shifting, is often impaired in children with specific learning disorder and contributes to classroom difficulties, off-task behavior, and reduced learning efficiency (Alizadeh, 2018; Amani et al., 2017). The present findings align with prior studies showing that executive function training, and working memory training in particular, can enhance behavioral regulation by improving children's ability to maintain task goals and inhibit irrelevant responses (Kirk et al., 2015; Thorell et al., 2009). From a neurocognitive

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perspective, repeated engagement of working memory processes may promote more efficient functioning of prefrontal networks responsible for top-down control, thereby translating into improved behavioral regulation in everyday contexts (Horowitz-Kraus, 2015; Kesler et al., 2018).

Improvements in metacognitive skills and total executive functions further support the effectiveness of the intervention. Metacognitive skills such as planning, organization, monitoring, and initiation are critical for academic success, particularly in students who must compensate for underlying learning difficulties (Maehler & Schuchardt, 2016; Magalhães et al., 2020). The substantial gains observed in the working memory training group are consistent with earlier intervention studies reporting that structured cognitive training programs can enhance higher-order executive processes beyond basic memory capacity (Abedi & Malekpour, 2010; Kamiabi et al., 2014). These findings lend support to the notion of transfer effects, whereby training a foundational cognitive process such as working memory leads to broader improvements in executive functioning, especially when training tasks are varied, progressively challenging, and embedded within meaningful cognitive activities (Dennis & Vander Wal, 2010; Thorell et al., 2009).

The results related to cognitive flexibility are also of particular importance. Cognitive flexibility, as assessed by performance on the Wisconsin Card Sorting Test, showed significant improvement in the working memory training group, reflected in an increased number of achieved categories and a reduction in perseverative errors. These findings are consistent with previous research demonstrating that children with specific learning disorder often exhibit rigid response patterns and difficulty adapting to changing task demands (Krause, 2015; Kunlin et al., 2017). By strengthening working memory capacity and updating processes, the intervention may have enabled participants to more effectively maintain and shift task rules, monitor feedback, and abandon ineffective strategies, all of which are essential components of cognitive flexibility (Jacques & Zelazo, 2005; Jongbloed-Pereboom et al., 2019). Similar improvements in cognitive flexibility following memory-based or cognitive rehabilitation interventions have been reported in both clinical and educational populations (Dehghani & Moradi, 2020; Zarei et al., 2020).

The maintenance of gains at follow-up further underscores the potential durability of working memory training effects. The absence of significant differences between posttest and follow-up scores suggests that participants were able to retain and possibly integrate the trained cognitive skills into their everyday functioning. This finding is consistent with studies indicating that when cognitive training programs are sufficiently intensive and structured, their effects may persist beyond the immediate training period (Kesler et al., 2018; Kirk et al., 2015). From an applied perspective, the stability of intervention effects is particularly important for students with specific learning disorder, as sustained improvements in executive functions and cognitive flexibility may support long-term academic adaptation and reduce cumulative learning difficulties (Swanson & Howard, 2005; Swanson & Jerman, 2007).

The present results also converge with broader evidence highlighting the central role of executive functions in academic achievement and learning trajectories. Executive functions, and cognitive flexibility in particular, have been shown to uniquely predict reading and mathematics outcomes across different grade levels, even after controlling for general intelligence and basic academic skills (Maehler & Schuchardt, 2016; Magalhães et al., 2020). By demonstrating that working memory training can enhance these executive capacities in students with specific learning disorder, the current study provides empirical support for incorporating cognitive training components into educational and rehabilitation programs for this population. These findings are also in line with systematic reviews suggesting that parent-involved and structured cognitive interventions can yield meaningful benefits for children with learning disabilities when implemented with sufficient intensity and methodological rigor (Guo & Keles, 2025; Veloso et al., 2020).

At a broader conceptual level, the findings support integrative models of learning disability that emphasize interactions between cognitive, emotional, and behavioral factors. Improvements in cognitive flexibility may not only facilitate academic problem solving but also contribute to more adaptive coping, reduced frustration, and greater resilience in challenging learning situations (Baron & Byrn, 2004; Gan et al., 2004). Prior research suggests that rigid cognitive styles are associated with heightened vulnerability to stress and maladaptive emotional responses, whereas greater flexibility supports adaptive adjustment and social functioning (Jafarzadeh Dashbalagh et al., 2019; Yovel et al., 2005). Therefore, the observed cognitive gains may have implications that extend beyond academic performance, potentially enhancing students' overall psychological well-being and social adaptation.

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5. Conclusion

Overall, the findings of the present study are consistent with emerging trends in cognitive and educational interventions that emphasize personalization, adaptability, and inclusivity. Advances in technology-based and AI-supported cognitive training programs have highlighted the potential for scalable and individualized interventions for learners with diverse needs (Gadekallu et al., 2025; Shao et al., 2025). Although the present study employed a non-digital, group-based working memory training program, the underlying principles of progressive challenge, feedback, and executive engagement align closely with these newer approaches. As such, the results provide a theoretically grounded rationale for integrating working memory training into both traditional and technology-enhanced intervention frameworks for students with specific learning disorder.

Despite these promising findings, several limitations of the present study should be acknowledged. The sample size was relatively small and drawn from a single urban context, which may limit the generalizability of the results to broader populations of students with specific learning disorder. Additionally, although a follow-up assessment was included, the follow-up period was relatively short, and longer-term outcomes remain unclear. The reliance on standardized neuropsychological and rating-scale measures, while methodologically sound, may not fully capture changes in real-world academic performance or classroom behavior. Furthermore, the study did not examine potential moderating variables such as severity of learning disorder, comorbid conditions, or family involvement, which may influence responsiveness to intervention.

Future research should aim to replicate these findings with larger and more diverse samples, including students from different age groups, educational settings, and cultural backgrounds. Longitudinal designs with extended follow-up periods would be valuable for assessing the long-term sustainability of working memory training effects and their impact on academic trajectories. Future studies may also benefit from comparing different types of cognitive training programs, including computerized, adaptive, and hybrid interventions, to determine which approaches yield the strongest and most transferable outcomes. Additionally, examining potential moderators and mediators of intervention effectiveness, such as baseline executive function levels, motivation, and parental involvement, could provide deeper insight into for whom and under what conditions working memory training is most effective.

From a practical perspective, the findings of the present study suggest that working memory training can be meaningfully integrated into educational and rehabilitation programs for students with specific learning disorder. Educators, school psychologists, and therapists may consider incorporating structured working memory exercises into individualized education plans and remedial curricula. Emphasis should be placed on consistency, gradual increase in task complexity, and opportunities for applying trained skills to academic activities. Collaboration between schools and families may further enhance the effectiveness of such interventions by promoting the generalization of cognitive skills across settings and supporting students' ongoing engagement in the training process.

Authors' Contributions

Authors equally contributed to this article.

Declaration

In order to correct and improve the academic writing of our paper, we have used the language model ChatGPT.

Transparency Statement

Data are available for research purposes upon reasonable request to the corresponding author.

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Declaration of Interest

The authors report no conflict of interest.

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Ethics Considerations

The study protocol adhered to the principles outlined in the Helsinki Declaration, which provides guidelines for ethical research involving human participants.

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References

Abedi, A., & Malekpour, M. (2010). The effectiveness of early psychological educational interventions on improving executive functions and attention in children with neuropsychological learning disabilities. *New Educational Approaches*, *5*(1). https://nea.ui.ac.ir/article_19039.html

Ahadi, H., & Kakavand, A. (2018). *Learning disabilities: From theory to practice*. Tehran: Arsbaran Publications.

Alizadeh, H. (2018). *Attention-deficit hyperactivity disorder: Characteristics, diagnosis, and treatment*. Tehran: Roshd Publications.

Alloway, T. C. (2007). Working memory, reading and mathematical skills in children with developmental coordination disorder. *Experimental Child Psychology*, *96*, 20-36. https://doi.org/10.1016/j.jecp.2006.07.002

Amani, A., Fadaei, E., Tavakoli, M., Shiri, I., & Shiri, V. (2017). A comparison of planning, selective attention, and cognitive flexibility in students with and without specific learning disabilities (reading impairment). *Learning Disabilities*, *7*(2), 94-111. https://www.sid.ir/paper/210226/fa

American Psychiatric, A. (2013). *Diagnostic and statistical manual of mental disorders DSM-5*. Washington DC, London, and England: Author. https://doi.org/10.1176/appi.books.9780890425596

American Psychiatric, A. (2015). *DSM-5-Manual Diagnóstico e Estatístico de Transtornos Mentais*. Porto Alegre: Artmed. https://books.google.com/books?hl=en&lr=&id=QL4rDAAAQBAJ&oi=fnd&pg=PT13&dq=American+Psychiatric,+A.+(2015).+DSM-5-Manual+Diagn%C3%B3stico+e+Estat%C3%ADstico+de+Transtornos+Mentais,+Porto+Alegre:+Artmed.+%09&ots=nS4BtJtaES&sig=Ge9CmSKD-KOVhuEMDzYgIcvsrUc

Aspen, H. Y., & Anne, G. E. (2022). How Working Memory and Reinforcement Learning Are Intertwined: A Cognitive, Neural, and Computational Perspective. *Journal of Cognitive Neuroscience*, *34*(4), 551-568. https://doi.org/10.1162/jocn_a_01808

Baron, R. A., & Byrn, D. (2004). *Social Psychology: Understanding Human Interaction*. Boston: Allyn and Bacon. https://books.google.com/books/about/Social_Psychology.html?id=GzaqAAAACAAJ

Dehghani, Y., & Moradi, N. A.-Z. (2020). The effect of active memory training on planning and cognitive flexibility in students with specific learning disabilities (dyslexia). *Neuropsychology*, *6*(20), 101-120. https://www.sid.ir/paper/266833/fa

Dennis, J. P., & Vander Wal, J. S. (2010). The cognitive flexibility inventory: Instrument development and estimates of reliability and validity. *Cognitive therapy and research*, *34*, 241-253. https://doi.org/10.1007/s10608-009-9276-4

Gadekallu, T. R., Yenduri, G., Kaluri, R., Rajput, D. S., Lakshmanna, K., Fang, K., & Wang, W. (2025). The role of GPT in promoting inclusive higher education for people with various learning disabilities: a review. *Peerj Computer Science*, *11*, e2400. https://doi.org/10.7717/peerj-cs.2400

Gan, Y., Liu, Y., & Zhang, Y. (2004). Flexible coping responses to severe acute respiratory syndrome-related and daily life stressful events. *Asian Journal of Social Psychology*, *7*, 55-66. https://doi.org/10.1111/j.1467-839X.2004.00134.x

Guo, L., & Keles, S. (2025). A systematic review of studies with parent-involved interventions for children with specific learning disabilities. *European Journal of Special Needs Education*, *40*(4), 755-772. https://doi.org/10.1080/08856257.2024.2421112

Horowitz-Kraus, K. (2015). Differential effect of cognitive training on executive functions and reading abilities in children with ADHD and in children with ADHD comorbid with reading difficulties. *Journal of Attention Disorders*, *19*(6), 515-526. https://doi.org/10.1177/1087054713502079

Jacques, S., & Zelazo, P. D. (2005). *On the possible roots of cognitive flexibility The Development of Social Cognition and Communication*. Mahwah, NJ: Lawrence Erlbaum. https://www.taylorfrancis.com/chapters/edit/10.4324/9781315805634-4/possible-roots-cognitive-flexibility-sophie-jacques-philip-david-zelazo

Jafarzadeh Dashbalagh, H., Janqoo, E., & Hemmati, B. (2019). The effectiveness of play therapy on improving information processing speed and social/emotional processing in students with specific learning disabilities in reading. *Journal of Learning Disabilities*, *9*(1), 71-91. https://jld.uma.ac.ir/article_834.html

Jongbloed-Pereboom, M., Nijhuis-van der Sanden, M. W. G., & Steenbergen, B. (2019). Explicit and implicit motor sequence learning in children and adults; the role of age and visual working memory. *Human Movement Science*, *64*, 1-11. https://doi.org/10.1016/j.humov.2018.12.007

Kamiabi, M., Timouri, S., & Mashhadi, A. (2014). The effectiveness of working memory training on reducing reading difficulties and improving working memory in dyslexic students. *Exceptional Education*, *2*(124), 33-41. https://www.sid.ir/paper/500551/fa

Kartini, A. G., & Susan, E. (2013). Working memory and study skills: a comparison between dyslexic and non-dyslexic adult learners. *Social and Behavioral Sciences*, *6*(97), 271-277. https://doi.org/10.1016/j.sbspro.2013.10.233

Kesler, S. R., Lacayo, N. J., & Jo, B. (2018). A pilot study of an online cognitive rehabilitation program for executive function skills in children with cancer-related brain injury. *Department of Psychiatry and Behavioral Sciences, Stanford University*, *25*(1), 101-112. https://doi.org/10.3109/02699052.2010.536194

Kirk, H. E., Gray, K., Riby, D. M., & Cornish, K. M. (2015). Cognitive training as a resolution for early executive function difficulties in children with intellectual disabilities. *Research in Developmental Disabilities*, *38*, 145-160. https://doi.org/10.1016/j.ridd.2014.12.026

Krause, T. H. (2015). Pinpointing the Deficit in Executive Functions in Adolescents with Dyslexia Performing the Wisconsin Card Sorting Test. *Journal of Learning Disabilities*, *47*(3), 208-223. https://doi.org/10.1177/0022219412453084

Kunlin, Z., Zili, F., Yufeng, W., Stephen, V., Faraone, L., & Suhua, C. (2017). Genetic analysis for cognitive flexibility in the trail-making test in attention deficit hyperactivity disorder patients from single nucleotide polymorphism, gene to pathway level. *World Journal of Biological Psychiatry*, *25*, 1-10. https://www.tandfonline.com/doi/shareview/10.1080/15622975.2017.1386324

Maehler, C., & Schuchardt, K. (2016). The importance of working memory for school achievement in primary school children with intellectual or learning disabilities. *Research in Developmental Disabilities*, *58*, 1-8. https://doi.org/10.1016/j.ridd.2016.08.007

Magalhães, S., Luísa, C., Teresa, L., & Filipe, G. (2020). Executive functions predict literacy and mathematics achievements: The unique contribution of cognitive flexibility in grades 2, 4, and 6. *Child Neuropsychology*, *26*(3), 421-430. https://doi.org/10.1080/09297049.2020.1740188

Pumaccahua, T. T., Wong, E. H., & Eeist, D. J. (2017). Effects of computerized cognitive training on working memory in a

E-ISSN: 3060-6713

school setting. *International Journal of Learning*, *16*(3), 88-104. https://ijlter.org/index.php/ijlter/article/download/863/pdf

Shao, J., Cui, Z., & Bao, Y. (2025). Adaptive sports programs as catalysts for social inclusion and cognitive flexibility in inclusive physical education: The mediating roles of emotional resilience and empathy. *BMC psychology*, *13*(1), 770. https://doi.org/10.1186/s40359-025-03092-2

Swanson, H. L., & Howard, C. B. (2005). Children with reading disabilities: Does dynamic assessment help in the classification? *Learning Disability Quarterly*, *28*, 17-34. https://doi.org/10.2307/4126971

Swanson, H. L., & Jerman, O. (2007). The influence of working memory on reading growth in subgroups of children with reading disabilities. *Experimental Child Psychology*, *96*, 249-283. https://doi.org/10.1016/j.jecp.2006.12.004

Thorell, L. B., Nutley, S. B., Bohlin, G., & Klingberg, T. (2009). Training and transfer effects of executive functions in preschool children. *Developmental science*, *12*(1), 106-113. https://doi.org/10.1111/j.1467-7687.2008.00745.x

Veloso, A., Selene, G., & Marisa, G. F. (2020). Effectiveness of Cognitive Training for School-Aged Children and Adolescents with Attention Deficit/Hyperactivity Disorder: A Systematic Review. *Frontiers in psychology*, *14*, 29-39. https://doi.org/10.3389/fpsyg.2019.02983

Yovel, I., Revelle, W., & Mineka, S. (2005). Who sees trees before forest? The obsessive-compulsive style of visual attention. *Psychological Science*, *16*(2), 123-129. https://doi.org/10.1111/j.0956-7976.2005.00792.x

Zarei, H., Charami, F., & Sharifi, A. A. (2020). The effectiveness of computer-based cognitive rehabilitation on working memory and cognitive flexibility in children with learning disabilities. *Cognitive Strategies in Learning*, *8*(15), 1-18. https://asj.basu.ac.ir/article_3481_446.html

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