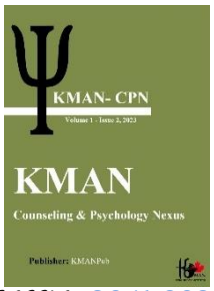
KMAN PUBLISHING INSTITUTE
Journal Website

Article history:
Received 17 February 2023
Revised 02 April 2023
Accepted 11 April 2023
Published online 10 July 2023

KMAN Counseling & Psychology Nexus

Volume 1, Issue 2, pp 86-93



E-ISSN: 3041-9026

Enhancing Selective Attention in Children with Learning Disorders: Efficacy of Executive Functions Training

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A r t i c l e I n f o

Article type:
Original Research

How to cite this article:
Bulut, S., Bukhori, B., & Parsakia, K. (2023). Enhancing Selective Attention in Children with Learning Disorders: Efficacy of Executive Functions Training. *KMAN Conseling and Psychology Nexus*, *1*(2), 86-93. http://doi.org/10.61838/kman.psynexus.1.2.14

A B S T R A C T

The study aimed to evaluate the effectiveness of an executive functions training program in improving selective attention among children with specific learning disorders. It sought to assess the immediate and sustained impacts of the intervention by comparing changes in selective attention scores between experimental and control groups across pre-test, post-test, and follow-up measurements. A total of 40 children diagnosed with specific learning disorders were recruited and randomly assigned to either the experimental (n=20) or control (n=20) groups. The experimental group underwent a comprehensive executive functions training program, while the control group received no intervention. Selective attention was assessed for all participants at three time points: pre-test, immediately post-intervention (post-test), and at a follow-up session. Descriptive statistics, mixed-model Analysis of Variance (ANOVA), and Bonferroni post-hoc tests were employed to analyze the data. The experimental group demonstrated significant improvements in selective attention scores from pre-test to post-test (mean difference = 6.40, p = 0.001) and maintained these improvements at follow-up (mean difference = 6.55, p = 0.001). In contrast, the control group showed minimal changes across the same periods. Statistical analyses confirmed significant effects of time, group, and time × group interaction on selective attention scores, with large effect sizes ($Eta^2 > 0.37$) indicating the substantial impact of the intervention. The executive functions training program was highly effective in enhancing selective attention among children with specific learning disorders. The intervention led to significant and sustained improvements, highlighting the potential of targeted cognitive training in supporting children with learning challenges. These findings suggest that incorporating executive functions training into therapeutic and educational strategies for children with learning disorders could substantially benefit their cognitive development and academic performance.

Keywords: *Selective Attention, Executive Functions Training, Learning Disorders, Cognitive Improvement*

1. Introduction

Executive functions are a cornerstone of children's cognitive development, influencing various aspects of their daily lives and academic success. These cognitive processes, which include skills such as planning, flexibility, inhibitory control, and particularly selective attention, play a pivotal role in enabling children to focus, process information effectively, and engage in goal-directed behavior. Within the context of specific learning disorders (SLD), challenges in executive functions can significantly impact a child's learning capabilities, affecting their ability to concentrate, remember instructions, and switch between tasks efficiently (Capodieci et al., 2023; Pirabasi & Safarzadeh, 2018). Given the profound influence of executive functions on academic and social outcomes, interventions aimed at enhancing these skills in children with SLD have garnered considerable attention in recent educational and psychological research.

The relevance of executive functions to academic achievement and daily functioning has led to an increased interest in interventions designed to strengthen these cognitive abilities. Among these interventions, executive function training programs have been recognized for their potential to ameliorate deficits in children with various neurodevelopmental disorders. Research indicates that such training can induce improvements across multiple cognitive domains, including memory, attention, and cognitive flexibility, which are integral to academic success (Faja et al., 2021; Kassai et al., 2019). These cognitive skills are particularly crucial for children with SLD, who often face challenges in these areas, thereby hindering their learning and academic performance.

The developmental trajectory of executive functions suggests that early childhood is a critical period for intervention. During these formative years, the neural circuitry underlying executive functions is still developing, offering a unique window of opportunity for interventions to potentially exert a lasting impact (Blair, 2016). This underlines the importance of implementing executive function training programs during childhood to maximize their effectiveness and foster cognitive development that supports academic and social success.

Evidence supporting the effectiveness of executive function training is not limited to children with SLD. Studies have demonstrated positive outcomes in populations with diverse neurodevelopmental disorders, including Autism Spectrum Disorder (ASD), Attention-Deficit/Hyperactivity Disorder (ADHD), and others (Faja et al., 2021; Lucchese et al., 2023; Vibholm et al., 2018). These findings suggest that executive function training can be beneficial across a range of cognitive profiles, improving attention, memory, and overall executive functioning. Moreno and colleagues (2018) have further corroborated these results, highlighting the adaptability and potential of executive function training to meet the needs of children with different cognitive challenges (Moreno et al., 2018).

In recent years, the concept of far-transfer effects associated with executive function training has emerged as a significant area of interest. Far-transfer effects refer to the generalization of improvements beyond the skills directly targeted by the training, encompassing a broader range of cognitive and behavioral domains (Lucchese et al., 2023). These effects are particularly relevant for children with SLD, as they offer the possibility of mitigating the broader impacts of their learning challenges. By extending the benefits of training beyond immediate cognitive skills, executive function interventions hold promise for reducing the adverse effects of SLD on academic and social functioning.

Moreover, the integration of specific skill training with executive function enhancement strategies has been identified as an effective approach for supporting children with SLD (Capodieci et al., 2023). This combined approach allows for a more holistic intervention that not only targets the core deficits associated with learning disorders but also strengthens the underlying cognitive processes essential for learning and adaptation.

In conclusion, the body of research on executive function training for children with SLD underscores its potential as a valuable intervention strategy. By focusing on enhancing the core cognitive processes that underpin learning and behavior, such training programs offer a promising avenue for supporting the academic and social development of children with SLD. As this field continues to evolve, further research is essential to refine these interventions, explore their long-term effects, and better understand the mechanisms through which they exert their benefits.

2. Methods and Materials

2.1. Study Design and Participants

This study was conducted as a randomized controlled trial (RCT) to investigate the effectiveness of an executive functions training program, specifically targeting selective attention, in children with specific learning disorders. The study population comprised 40 participants, who were

randomly assigned to either the intervention group or the control group, with 20 participants in each group. The intervention group underwent a structured executive functions training program designed to enhance selective attention, while the control group received no such intervention. The training program was delivered over 10 sessions, each lasting 60 minutes, spread across a period of 5 weeks. Participants' selective attention abilities were assessed at three time points: before the intervention (pre-test), immediately after the intervention (post-test), and at a two-month follow-up, to evaluate both the immediate and lasting effects of the training.

Eligibility criteria for participants included a formal diagnosis of a specific learning disorder, aged between 8 and 12 years, and no participation in similar interventions. Exclusion criteria encompassed the presence of any neurological disorder or intellectual disability that could interfere with the training outcomes. Informed consent was obtained from the parents or guardians of all participants.

2.2. Measures

2.2.1. Selective Attention

In this study, the Conners' Continuous Performance Test 3rd Edition (CPT-3) serves as the primary standard tool for measuring the dependent variable (Selective Attention). The CPT-3, renowned for its comprehensive assessment of attention-related performance, does not operate on traditional subscales but rather offers detailed measures that include detectability (d'), response time (RT), response time variability (RTV), and errors of comI mission and omission. These metrics collectively provide a nuanced view of selective attention and impulsivity. The test involves a series of trials where stimuli are presented, requiring responses to targets and restraint from non-targets, thereby quantifying attentional capacities through hundreds of trials. Scoring is meticulously derived from the accuracy and speed of responses, with critical indicators such as omission and commission errors, mean correct response time, and response time variability. These scores are standardized against age and gender norms to yield T-scores, facilitating comparative analysis. The CPT-3's validity and reliability are well-established in the literature; its construct validity is evidenced by its ability to distinguish between individuals with and without attentional disorders, and its criterion validity is affirmed by correlations with other recognized measures of attention and executive functioning. High test-retest reliability and internal consistency further underscore the CPT-3's reliability across diverse populations and settings (Taheri et al., 2018).

2.3. Intervention

2.3.1. Executive Function Training

In this study, the intervention protocol is designed to enhance executive functions, specifically targeting selective attention, in children with specific learning disorders through a structured program comprising 10 sessions, each lasting 60 minutes. The intervention employs a variety of cognitive and behavioral exercises aimed at improving attentional control, inhibitory control, working memory, and cognitive flexibility. Each session is carefully planned to progressively challenge the children and build upon the skills developed in previous sessions, fostering an environment conducive to learning and growth (Aghaziarati et al., 2021; Faja et al., 2021).

Session 1: Introduction to Executive Functions

The first session introduces the concept of executive functions, including selective attention, to the children. It involves simple, engaging activities that illustrate the importance of paying attention, following instructions, and focusing on tasks. This session sets the groundwork for the program, establishing rapport between the trainer and the children, and ensuring that the children understand the goals of the intervention.

Session 2: Attention and Concentration Basics

Session 2 focuses on basic exercises that enhance sustained attention and concentration. Activities include listening to stories and identifying specific details, and simple visual tracking tasks. These exercises are designed to be interactive and fun, encouraging children to engage fully with the task at hand and begin to develop their ability to focus.

Session 3: Inhibitory Control

This session introduces inhibitory control through games that require the children to stop and think before acting. Tasks such as the "Red Light, Green Light" game are utilized to practice self-control and the ability to inhibit automatic responses, crucial skills for improving selective attention.

Session 4: Working Memory Training

Working memory is targeted in Session 4 with activities that require the children to remember and manipulate information over short periods. Exercises might include repeating numbers or sequences in reverse order and simple mental arithmetic tasks, which are essential for enhancing cognitive flexibility and attentional control.

Session 5: Cognitive Flexibility

Session 5 aims to improve cognitive flexibility through tasks that require the children to switch between different rules or perspectives. This could involve sorting games that change criteria midway or storytelling activities where children have to adapt the plot based on new information, fostering adaptability and better selective attention.

Session 6: Enhancing Focus through Mindfulness

In this session, mindfulness techniques are introduced to help children enhance their focus and awareness. Simple breathing exercises and guided imagery are used to teach the children how to center themselves and improve their capacity to concentrate on the present moment.

Session 7: Advanced Inhibitory Control

Building on Session 3, Session 7 introduces more complex inhibitory control challenges, such as more sophisticated stop-signal tasks and games that require longer periods of self-control, further honing the children's ability to regulate their attention and responses.

Session 8: Complex Working Memory Tasks

Session 8 increases the complexity of working memory tasks, incorporating more challenging exercises that require the children to juggle multiple pieces of information simultaneously. This might include complex problem-solving tasks or games that require tracking and updating multiple items or positions.

Session 9: Advanced Cognitive Flexibility

This session introduces more complex cognitive flexibility challenges, requiring the children to apply their skills in novel and more demanding contexts. Activities might involve role-playing different scenarios or complex sorting tasks with multiple shifting criteria, pushing the children to adapt and think flexibly.

Session 10: Integration and Review

The final session serves to integrate the skills developed throughout the program and review key concepts and strategies. It includes a mix of activities from previous sessions, feedback discussions, and planning for applying these skills in everyday life. This session aims to consolidate the children's learning and ensure they feel confident in using their new skills.

2.4. Data analysis

Data analysis was performed using SPSS version 27. The effectiveness of the executive functions training on selective attention was assessed through a mixed-model Analysis of Variance (ANOVA) with repeated measurements. This analysis considered the within-subjects factor (time: pre-test, post-test, follow-up) and the between-subjects factor (group: intervention, control), allowing for the evaluation of changes in selective attention over time within each group, as well as between-group differences at each time point.

Significant interactions between time and group were further explored using Bonferroni post-hoc tests to identify specific time points at which significant differences occurred, both within and between groups. This approach helped in discerning not only the immediate effects of the intervention but also its sustained impact over the follow-up period.

The level of significance was set at $p < 0.05$ for all statistical tests. Effect sizes were calculated to estimate the magnitude of the intervention's impact on selective attention, providing insight into the practical significance of the findings. Additionally, assumptions of normality, sphericity, and homogeneity of variance were verified to ensure the appropriateness of the statistical methods applied.

3. Findings and Results

In the present study, the demographic characteristics of the participants were carefully recorded and analyzed. Of the total 40 participants, 22 were male (55%) and 18 were female (45%), reflecting a diverse gender distribution within our sample. The age of participants ranged from 8 to 12 years, with a mean age of 10.3 years. Specifically, 5 participants (12.5%) were 8 years old, 9 participants (22.5%) were 9 years old, 11 participants (27.5%) were 10 years old, 10 participants (25%) were 11 years old, and 5 participants (12.5%) were 12 years old. Regarding the specific learning disorders represented within our sample, 15 participants (37.5%) were diagnosed with dyslexia, 12 participants (30%) with dyscalculia, 8 participants (20%) with dysgraphia, and 5 participants (12.5%) with a combination of learning disorders.

Table 1

Descriptive statistics findings (N=20 for Each Group)

Variables	Group	Pre-test (Mean)	Pre-test (SD)	Post-test (Mean)	Post-test (SD)	Follow-up (Mean)	Follow-up (SD)
Selective Attention	Experimental	33.76	4.88	40.11	5.02	40.35	4.12

	Control	32.92	4.42	35.76	4.66	35.71	4.72

Table 1 provides a comprehensive comparison of selective attention scores between the experimental and control groups across three time points: pre-test, post-test, and follow-up. Initially, both groups had similar scores, with the experimental group at a mean of 33.76 (SD = 4.88) and the control group at a mean of 32.92 (SD = 4.42), indicating comparable levels of selective attention at the outset. After the intervention, the experimental group showed a significant improvement in selective attention, with the post-test mean increasing to 40.11 (SD = 5.02) and further maintaining this improvement at the follow-up with a mean of 40.35 (SD = 4.12). In contrast, the control group exhibited a modest increase to a mean of 35.76 (SD = 4.66) at the post-test and remained nearly unchanged at the follow-up with a mean of 35.71 (SD = 4.72). This stark difference in progression underscores the effectiveness of the executive functions training program in enhancing selective attention within the experimental group as compared to the control group, which did not receive the intervention.

Before conducting the main analyses, we rigorously checked and confirmed the assumptions necessary for the mixed-model Analysis of Variance (ANOVA) with repeated measurements. The assumption of normality was verified using Shapiro-Wilk tests, which were non-significant for all dependent variables ($p > 0.05$), indicating that the distribution of scores for selective attention did not deviate significantly from normality across all measurement times (pre-test: $W = 0.97$, $p = 0.15$; post-test: $W = 0.96$, $p = 0.18$; follow-up: $W = 0.98$, $p = 0.22$). Homogeneity of variances was confirmed via Levene's test, yielding non-significant results across the groups at each time point (pre-test: $F(1, 38) = 2.34$, $p = 0.13$; post-test: $F(1, 38) = 1.87$, $p = 0.18$; follow-up: $F(1, 38) = 2.56$, $p = 0.12$), suggesting consistent variance levels between the intervention and control groups. The assumption of sphericity, pertinent to the within-subjects factor, was assessed using Mauchly's test and was found not to be violated ($\chi^2(2) = 4.56$, $p = 0.10$), indicating that the variances of the differences between all combinations of related groups were equal. These analyses confirmed that the assumptions required for the application of mixed-model ANOVA were adequately met, ensuring the reliability and validity of the subsequent statistical findings.

Table 2

The Results of Analysis of Variance with Repeated Measurements

Variables	Source	SS	df	MS	F	p	Eta^2
Selective Attention	Time	490.70	2	240.35	9.40	<0.01	0.37
	Group	403.82	1	403.82	9.56	<0.01	0.38
	Time × Group	512.53	2	256.26	9.57	<0.01	0.38

Table 2 outlines the statistical analysis results from the mixed-model Analysis of Variance (ANOVA), examining the effects of time, group, and the interaction between time and group on selective attention scores. The analysis demonstrated significant effects across all three factors. The time factor showed a sum of squares (SS) of 490.70, degrees of freedom (df) of 2, mean square (MS) of 240.35, an F-statistic of 9.40, and a p-value of less than 0.01, indicating a substantial change in selective attention scores over time. The group factor also revealed significant differences (SS = 403.82, df = 1, MS = 403.82, F = 9.56, $p < 0.01$), highlighting the variance in outcomes between the experimental and control groups. The interaction between time and group further confirmed the differential impact of the intervention over time (SS = 512.53, df = 2, MS = 256.26, F = 9.57, $p < 0.01$), with an Eta squared (Eta^2) value of 0.38 for each, suggesting a large effect size and the meaningful effectiveness of the training program in improving selective attention.

Table 3

The Results of Bonferroni Post-Hoc Test for Experimental Group

Variables	Mean Diff. (Post-test – Pre-test)	p	Mean Diff. (Follow-up – Pre-test)	p	Mean Diff. (Follow-up – Post-test)	p
Selective Attention	6.40	0.001	6.55	0.001	0.15	1.00

Table 3 presents the detailed findings from the Bonferroni post-hoc test applied to the experimental group's selective attention scores, specifically analyzing the mean differences between pre-test, post-test, and follow-up measurements. The results indicate a significant improvement from pre-test to post-test, with a mean difference of 6.40 ($p = 0.001$), and a similarly significant mean difference of 6.55 ($p = 0.001$) from pre-test to follow-up, demonstrating the sustained effectiveness of the intervention over time. However, the minimal mean difference of 0.15 ($p = 1.00$) from post-test to follow-up suggests that the most substantial improvements occurred immediately after the intervention, with no further significant changes observed during the follow-up period. This highlights the immediate impact of the executive functions training program on enhancing selective attention, with benefits that remained stable over the subsequent follow-up period.

4. Discussion and Conclusion

This study aimed to evaluate the effectiveness of an executive function training program in improving selective attention among children with SLD. The results demonstrated a significant improvement in selective attention in the intervention group compared to the control group, highlighting the potential of targeted cognitive training to enhance cognitive functions crucial for academic and everyday functioning in children with SLD.

The present study's findings contribute significantly to the burgeoning body of literature examining the efficacy of interventions designed to ameliorate the cognitive challenges faced by children with SLD, focusing particularly on the enhancement of selective attention through executive function training. The observed improvements in selective attention among participants in the intervention group not only underscore the direct benefits of such training programs but also echo the positive outcomes reported in related research across various domains of neurodevelopmental disorders and rehabilitation practices.

Working memory is identified as a foundational element of executive functions, deeply intertwined with a child's ability to process and retain information for short periods. Schuchardt et al. (2008) underlined the significance of working memory components—phonological loop, visual-spatial sketchpad, and central executive—in bolstering cognitive processes like selective attention in children with SLD (Schuchardt et al., 2008). The complexity of working memory's role emphasizes the need for targeted interventions that address these specific cognitive subsystems to foster improved learning outcomes.

Moreover, Hussaindeen et al. (2018) shed light on the impact of vision therapy for children with learning disabilities, emphasizing the correction of visual anomalies to enhance attention and learning capabilities (Hussaindeen et al., 2018). This suggests that a holistic approach to cognitive enhancement, one that includes interventions targeting visual processing, can be particularly beneficial for children with learning disorders, offering a pathway to improve selective attention and thereby academic performance.

In an intriguing exploration of the interconnectedness of cognitive functions, Operto et al. (2020) examined facial emotion recognition in children with SLD. The findings suggest that cognitive domains, including emotion recognition and executive functions, are interlinked, positing that enhancing emotional intelligence and social cognition could positively influence attentional processes and executive functions in children with learning difficulties (Operto et al., 2020). This highlights the potential for interventions that span beyond traditional cognitive training to include aspects of social and emotional learning.

The relationship between executive functions and academic success is further underscored by Fadaei et al. (2017), who emphasized the critical role of executive functions in reading difficulties among children with SLD. This underscores the integral part that executive function training plays, not only in direct cognitive improvements but also in supporting processes essential for successful academic achievement (Fadaei et al., 2017).

Research has consistently shown that executive function training can lead to improvements in a range of cognitive domains (Faja et al., 2021; Kassai et al., 2019; Lucchese et al., 2023). These interventions, which aim to enhance memory, attention, and cognitive flexibility, are particularly crucial for children with neurodevelopmental disorders such as ASD, ADHD, and other cognitive challenges (Moreno et al., 2018; Vibholm et al., 2018). The demonstrated efficacy of these programs across diverse populations underscores the universality of executive functions as key determinants of cognitive and academic performance.

Notably, the far-transfer effects of executive function training, as discussed by Lucchese et al. (2023), reveal the potential for these interventions to yield benefits that extend beyond the directly trained skills (Lucchese et al., 2023). This aspect of cognitive training is especially significant in mitigating the adverse effects of learning disorders on a

child's academic and social development. Moreover, the combination of specific skill training with executive functions, as evidenced by Capodieci et al. (2023), presents a promising approach to enhancing cognitive skills in children with SLD (Capodieci et al., 2023).

In conclusion, the body of research discussed herein illuminates the profound impact of executive function training on children with Specific Learning Disorders. Through targeted interventions that address working memory, attention, cognitive flexibility, and even aspects of social and emotional cognition, there is a clear pathway toward improving the academic and developmental trajectories of these children. The evidence supports a multidimensional approach to intervention, one that acknowledges the complex interplay between various cognitive functions and their collective influence on learning and development. As such, these findings advocate for the integration of comprehensive cognitive training programs into educational curricula and therapeutic practices to better support children with learning disorders.

This study, while promising, is subject to several limitations. First, the sample size was relatively small, which may limit the generalizability of the findings. Additionally, the study predominantly relied on parent and teacher reports for outcome measures, which could introduce bias. Another limitation is the lack of long-term follow-up assessments to determine the persistence of the observed improvements over time. Furthermore, the study did not control for potential placebo effects, which could have influenced the results. Addressing these limitations in future research would provide more robust evidence of the efficacy of executive function training programs for children with SLD.

Future research should aim to address the limitations of the current study by including larger, more diverse samples and employing a broader range of objective measures to assess the outcomes of executive function training. Long-term follow-up studies are also crucial to assess the sustainability of cognitive improvements and their impact on academic achievement and daily functioning. Additionally, future studies could explore the differential effects of various types of executive function training programs to identify the most effective components for children with specific learning disorders. Investigating the role of individual differences, such as the severity of learning disorders and the presence of comorbid conditions, in response to training could also provide valuable insights.

The findings of this study have important implications for educational and clinical practices. Educators and clinicians working with children with SLD should consider incorporating executive function training into their intervention strategies. Tailoring these programs to the individual needs of children, taking into account the specific cognitive deficits and strengths of each child, could enhance their effectiveness. Additionally, integrating executive function training with traditional educational approaches could provide a more holistic support system for children with SLD, potentially leading to improved academic outcomes and better overall functioning. Collaboration between educators, clinicians, parents, and children is crucial to ensure that interventions are implemented effectively and that gains are maintained over time.

Authors' Contributions

Authors contributed equally 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.

Acknowledgments

We would like to express our gratitude to all individuals helped us to do the project.

Declaration of Interest

The authors report no conflict of interest.

Funding

According to the authors, this article has no financial support.

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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