KMAN PUBLISHING INSTITUTE
Journal Website
Article history:
Received 28 March 2026
Revised 17 June 2026
Accepted 25 July 2026
Initial Publication 26 July 2026
Final Publication 10 September 2026

Psychological Research in Individuals with Exceptional Needs

Volume 4, Issue 3, pp 1-15

E-ISSN: 3060-6713

Development of a Computerized Cognitive Skills Package and Evaluation of Its Effectiveness on Selective Attention, Response Inhibition, and Working Memory in Children with Dyslexia

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Article Info

Article type:
Original Research

How to cite this article:
Mousavi, A. H., Asaseh, M., & Kozegar, E. (2026). Development of a Computerized Cognitive Skills Package and Evaluation of Its Effectiveness on Selective Attention, Response Inhibition, and Working Memory in Children with Dyslexia. *Psychological Research in Individuals with Exceptional Needs, 4*(3), 1-15.
https://doi.org/10.61838/kman.prien.5857

ABSTRACT

The present study aimed to develop a computerized cognitive skills package and investigate its effects on selective attention, response inhibition, and working memory in children with dyslexia. In the package-development phase, a qualitative research method was employed in two stages. In the first stage, a triangulation strategy was used to enhance the credibility of the findings. In the second stage, the designed computerized package was validated using the Delphi method and the opinions of 10 psychology specialists. The quantitative phase employed a quasi-experimental design. Thirty third-, fourth-, and fifth-grade children in Tabriz were selected through convenience sampling and randomly assigned to an experimental group and a control group, with 15 participants in each group. Following the implementation of the researcher-developed computerized cognitive skills package for the experimental group, the d2 Test, Stroop Test, and N-back Test were administered to both groups as posttests. The resulting data were subsequently analyzed using one-way analysis of variance. The findings indicated significant differences between the experimental and control groups in selective attention, response inhibition, and working memory. It can therefore be concluded that the developed computerized cognitive skills package is effective in improving selective attention, response inhibition, and working memory among children with dyslexia.

Keywords: *computerized cognitive skills package, dyslexia, selective attention, response inhibition, working memory.*

1. Introduction

Reading is a complex cognitive and linguistic achievement that requires the coordinated operation of perceptual processing, phonological analysis, lexical access, working memory, attentional control, and executive regulation. Difficulties in any of these systems may disrupt the development of fluent and accurate reading, particularly during the early years of formal schooling. Dyslexia is classified as a neurodevelopmental learning disorder characterized by persistent difficulties in accurate or fluent word recognition, decoding, and spelling that cannot be adequately explained by low intelligence, inadequate instruction, sensory impairment, or insufficient educational opportunity (American Psychiatric, 2023). Although dyslexia is most visibly manifested in reading performance, contemporary cognitive and developmental perspectives increasingly describe it as a multidimensional condition involving interactions among phonological processing, visual attention, working memory, processing speed, inhibitory control, and broader executive functions. This broader conceptualization is important because children with dyslexia often experience difficulties that extend beyond reading accuracy and influence classroom participation, task completion, academic motivation, and educational adjustment. Evidence from developmental cognitive neuroscience indicates that learning disabilities emerge through dynamic interactions among domain-specific learning mechanisms and domain-general executive systems, and that reading difficulties cannot be fully understood without considering the developmental contribution of executive functioning (Horowitz-Kraus et al., 2026). Accordingly, interventions that address only the mechanical aspects of decoding may not sufficiently remediate the cognitive constraints that interfere with reading acquisition and reading comprehension.

Executive functions refer to a set of higher-order cognitive processes that enable individuals to regulate goal-directed behavior, resist irrelevant responses, maintain information, shift between task demands, plan actions, and monitor performance. These processes are especially important in educational contexts, where students must focus on relevant stimuli, ignore distractions, retain instructions, manipulate information, and inhibit impulsive or inappropriate responses. Research has consistently shown that executive functions are related not only to academic performance but also to adaptive behavior and everyday self-regulation. A systematic review and meta-analysis demonstrated meaningful associations between executive functioning and health-related behaviors, emphasizing the broader role of executive control in organizing behavior across contexts (Gray-Burrows et al., 2019). In children, executive functions also contribute to the acquisition of foundational academic skills, including numerical competence, literacy, and problem solving. For example, individual differences in basic numerical abilities have been linked to executive and motor functions, illustrating how cognitive control supports learning even in domains that may initially appear highly specific (Gashaj et al., 2019). In children with learning disorders, weaknesses in executive functions may therefore intensify academic difficulties by reducing the efficiency with which cognitive resources are allocated to reading, writing, and classroom tasks. Iranian research has similarly emphasized the role of executive functions in children with learning disorders and has identified these processes as important explanatory mechanisms for their educational difficulties (Yaghoubi et al., 2016).

Among the executive functions associated with reading, selective attention is of particular importance. Selective attention allows an individual to prioritize task-relevant information while suppressing competing or distracting stimuli. During reading, children must distinguish visually similar letters, maintain their focus on the relevant part of a word or sentence, ignore surrounding visual information, and coordinate successive eye movements across text. Deficits in this process may lead to omissions, substitutions, slow decoding, loss of place, and reduced reading fluency. Comparative evidence has shown that students with specific learning disorders involving reading deficiencies perform less effectively than typically developing students in selective attention, planning, and cognitive flexibility (Amani et al., 2018). A scoping review of visual selective attention and visual search in children with dyslexia, attention-deficit/hyperactivity disorder, and cerebral visual impairment further demonstrated that atypical attentional patterns constitute an important feature of dyslexia and may contribute to inefficiency in visual search and reading-related processing (Hokken et al., 2023). Neurophysiological findings also indicate atypical mechanisms of visual selective attention in children with dyslexia, suggesting abnormalities in the allocation of attention to relevant stimuli and in the suppression of distractors (Liu et al., 2024). These findings support the view that selective attention is not merely an accompanying difficulty but may represent a central cognitive target in interventions designed for children with dyslexia.

Response inhibition is another essential component of executive functioning that is closely related to successful reading and learning. Response inhibition refers to the ability to suppress a dominant, automatic, impulsive, or no-longer-relevant response in favor of a more appropriate action. During reading, children must inhibit incorrect phonological associations, suppress premature guesses, resist distraction, and revise responses when new linguistic information becomes available. Weak inhibition can result in impulsive decoding, repetition of errors, difficulty correcting misread words, and reduced control over reading strategies. Research on adolescents with dyslexia using tasks such as the Wisconsin Card Sorting Test has identified executive-function deficits involving cognitive control and regulation, indicating that dyslexia may be associated with difficulties beyond phonological processing alone (Krause, 2015). The importance of inhibition is also supported by evidence that strategy-based games can influence inhibitory performance, although the magnitude and direction of such effects may depend on the cognitive demands of the game (Leong et al., 2022). Intervention research in kindergarten classrooms likewise suggests that inhibitory control can be strengthened through systematic practice and developmentally appropriate activities (Lambert, 2021). Moreover, response inhibition is influenced by multiple behavioral and physiological factors, as demonstrated by findings concerning the relationship between cardiovascular fitness and inhibition ability (Baghlari et al., 2018). These findings collectively indicate that inhibition is a modifiable capacity and a potentially valuable intervention target for children whose reading problems are accompanied by impulsivity, poor error monitoring, and inefficient attentional regulation.

Working memory is equally fundamental to reading development because it enables the temporary storage and manipulation of information during ongoing cognitive activity. In reading, working memory supports the retention of phonemes while they are blended into words, the maintenance of words across a sentence, the integration of current information with prior text, and the construction of coherent meaning. Children with weak working memory may decode individual words but fail to retain them long enough to understand sentences or paragraphs. They may also struggle to follow multistep instructions, remember spelling patterns, and coordinate decoding with comprehension. Research examining working-memory interventions among students with reading comprehension difficulties has shown that targeted training can improve cognitive performance and may support aspects of reading comprehension (Novaes et al., 2019). Cognitive rehabilitation has also been associated with improvements in working memory and verbal fluency among students with dyslexia, indicating that repeated and structured cognitive exercises may enhance processes directly relevant to reading performance (Farhad et al., 2016). Similarly, computerized cognitive educational interventions focused on working memory have produced improvements in attention, response control, and the central executive component of working memory among students with specific learning disorders (Khaksar Boldaji et al., 2018). These results reinforce the interdependence of working memory, attention, and inhibition and suggest that integrated interventions may be more effective than programs that address these abilities separately.

Cognitive rehabilitation is based on the assumption that cognitive abilities can be strengthened through systematic, repetitive, adaptive, and goal-directed practice. It commonly includes exercises designed to improve attention, memory, processing speed, executive control, and problem solving. Although cognitive rehabilitation was initially developed extensively in neurological and clinical settings, it has increasingly been applied to developmental and educational disorders. Reviews of cognitive rehabilitation among individuals with brain tumors, for example, have shown that structured cognitive interventions can support cognitive functioning and daily performance, thereby demonstrating the broader neuroplastic potential of rehabilitation methods (Bergo et al., 2016). In educational populations, computerized cognitive rehabilitation has reduced cognitive failures among students with learning disabilities (Abbariki et al., 2017). Cognitive rehabilitation has also improved selective attention and executive functioning in students with attention-deficit/hyperactivity disorder (Kamarzarin et al., 2019), while the Aram cognitive rehabilitation package has enhanced executive functions in preschool children with symptoms of attention-deficit/hyperactivity disorder (Maghsoudlou et al., 2019). Similar benefits have been reported in older adults with mild cognitive impairment, where cognitive rehabilitation improved selective attention, inhibitory control, and working memory (Nazarboland et al., 2019). Although these populations differ from children with dyslexia, the consistency of these findings suggests that targeted cognitive practice can produce measurable improvements across age groups and diagnostic conditions.

E-ISSN: 3060-6713

Computerized cognitive training offers several advantages over conventional paper-and-pencil interventions. Digital environments can present stimuli rapidly and accurately, record response times and errors, provide immediate feedback, adjust difficulty according to performance, and maintain motivation through game-like elements. These features are particularly relevant for children who may experience frustration, fatigue, or low engagement during traditional remedial instruction. Computerized programs can also standardize the delivery of intervention content while allowing repeated practice without excessive reliance on therapist-led instruction. A randomized controlled trial demonstrated that video-game training could improve selective attention and working memory, providing evidence that digital training environments may modify core cognitive processes (Ballesteros et al., 2017). Attention-memory training has also produced behavioral and academic improvements in children with attention-deficit/hyperactivity disorder and comorbid learning disorders, suggesting that cognitive training may influence both laboratory-based measures and functional educational outcomes (Carlos Farias et al., 2017). More recent systematic evidence indicates that computerized cognitive training can improve selected cognitive outcomes in children and adolescents with neurodevelopmental disorders, although intervention effects depend on program characteristics, training intensity, and outcome measures (Lin et al., 2025). Furthermore, serious games have increasingly been used to strengthen executive functions in neurodiverse children because they combine therapeutic objectives with interactive, motivating, and adaptive task structures (Rodriguez Timana et al., 2024).

The use of game-based and computerized cognitive activities is particularly promising when intervention tasks are designed according to the specific cognitive profile of the target population. Cognitive games have been shown to improve attention and response inhibition in students with dyscalculia, demonstrating that game-based training can target executive processes in children with learning disorders (Arjmandnia et al., 2018). Nevertheless, the effectiveness of such programs depends on the alignment between training exercises and the cognitive deficits they are intended to address. Programs that merely use attractive digital features without a coherent theoretical structure may improve task familiarity rather than generate transferable cognitive gains. Systematic research on current approaches to cognitive skills in children with dyslexia emphasizes the need to integrate phonological, attentional, memory-related, and executive components rather than relying on a single-domain intervention (Akyurek et al., 2024). This integration is especially important because reading performance involves the simultaneous coordination of lower-level linguistic skills and higher-level cognitive control. In addition, children's emotional regulation and resilience may affect their persistence and engagement in intervention programs, particularly when repeated academic failure has contributed to frustration or avoidance (Shafiei Tabar & Akbari Chaharmini, 2022). Therefore, an effective computerized package for dyslexia should be developmentally appropriate, cognitively targeted, sufficiently engaging, and capable of linking executive-function training with reading-related exercises.

Recent Iranian studies provide further support for computerized cognitive rehabilitation in students with dyslexia. The Captain's Log computerized cognitive rehabilitation program has been reported to improve both reading performance and executive functions in elementary school students with dyslexia (Shamshiri et al., 2024). Comparative research has also found that computerized cognitive rehabilitation and cognitive-behavioral play therapy can improve executive functions in students with dyslexia, although the two approaches may differ in their relative effects on specific outcomes (Mina Shamshiri et al., 2025). Similar comparative evidence has indicated that both computerized cognitive rehabilitation and cognitive-behavioral play therapy are effective in enhancing executive functions in this population (M. Shamshiri et al., 2025). Another study comparing these interventions also demonstrated improvements in executive functioning among students with dyslexia and reinforced the therapeutic value of structured computer-based practice (D. Shamshiri et al., 2025). Moreover, research comparing cognitive-behavioral play therapy with cognitive rehabilitation has reported positive effects on the academic achievement of students with dyslexia, suggesting that cognitive gains may extend to educational performance (Shakeri Chenari et al., 2026). These studies indicate a growing interest in technology-assisted interventions for dyslexia; however, many available programs are imported, diagnosis-specific only in a general sense, or focused on a limited range of cognitive skills.

Despite promising findings, several limitations remain in the existing literature. First, many cognitive rehabilitation programs are designed for general executive dysfunction rather than specifically for the cognitive and reading-related needs of children with dyslexia. Second, some interventions focus primarily on a single process, such as working memory

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or attention, whereas dyslexia often involves interacting difficulties in selective attention, inhibitory control, working memory, phonological awareness, letter recognition, reading fluency, and comprehension. Third, the content validity of intervention packages is not always systematically examined through expert consensus, content validity ratios, and content validity indices. Fourth, the experiences of children, families, and practitioners are sometimes insufficiently incorporated into program development. Qualitative research on students with specific learning difficulties has shown that the structure of learning environments, instructional accessibility, technological design, and learner experience can substantially shape educational participation (Podsiadlik, 2023). Consequently, intervention development should not be based exclusively on theoretical assumptions; it should also include evidence from prior studies, analysis of existing programs, assessment of children's needs, and expert validation.

Another important limitation concerns the measurement of training outcomes. The effectiveness of computerized cognitive interventions should be assessed with standardized tasks that distinguish among selective attention, inhibitory control, and working memory. The Stroop Color–Word Test is widely used to evaluate interference control, response inhibition, and selective attention, and research has supported its utility in neuropsychological assessment, although performance validity and contextual interpretation must be carefully considered (Lee et al., 2019). Cognitive outcomes should also be evaluated through tasks with sufficient sensitivity to changes in information processing, sustained effort, error control, and memory updating. In addition, the transfer of training from computerized exercises to reading behavior and classroom functioning remains a critical issue. Evidence suggests that cognitive training can produce benefits, but such effects are most likely when exercises are sufficiently intensive, progressively challenging, and closely related to the cognitive demands of everyday tasks. Accordingly, a package developed for children with dyslexia should combine exercises targeting reading foundations with tasks designed to strengthen the executive mechanisms that support accurate and fluent reading.

Theoretical and empirical evidence therefore supports the development of a comprehensive computerized cognitive skills package tailored to children with dyslexia. Such a package should address phonological awareness, letter recognition, phoneme blending, reading fluency, and reading comprehension while simultaneously strengthening selective attention, response inhibition, and working memory through interactive cognitive games. A multimethod development process involving literature review, evaluation of existing domestic and international packages, needs assessment among children with dyslexia, and expert validation can increase the scientific relevance and cultural appropriateness of the resulting intervention. It may also help bridge the gap between cognitive rehabilitation and direct reading instruction by embedding executive-function exercises within a structured educational sequence.

Accordingly, the aim of the present study was to develop a computerized cognitive skills package and evaluate its effectiveness in improving selective attention, response inhibition, and working memory in children with dyslexia.

2. Methods and Materials

2.1. Study Design and Participants

Given the nature of the research problem, the present study employed a mixed-methods design. In the development of the educational package, a qualitative method was used in two stages. In the first stage, a triangulation strategy was employed to enhance the credibility of the findings. In the second stage, the designed computerized package was validated using the Delphi method. The research population in the first stage comprised three groups. The first population consisted of articles and studies published during the preceding 10 years on dyslexia, executive functions, effective cognitive games, and innovative instructional methods, retrieved from international and Persian-language databases. From these sources, 50 articles were selected on the basis of thematic relevance. The second population comprised internationally and domestically developed computerized packages in the areas of alphabet instruction, cognitive games, and dyslexia. From these packages, 10 were selected through convenience sampling and subsequently reviewed. The third population consisted of students with dyslexia in Tabriz. Among these students, those who had attended the Arman Psychological Center were selected through convenience sampling to identify and examine their needs and challenges.

In the second stage, the designed computerized package was validated using the Delphi method. The statistical population consisted of specialists in educational psychology between 40 and 70 years of age. Ten specialists were selected through convenience sampling, and the content of the computerized package was provided to them

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for evaluation. First, the general objectives of the educational protocol, together with the objectives and content of each component, were explained. The specialists were then asked to rate their level of agreement with each session in terms of two criteria—relevance to the program and necessity of inclusion—on a six-point Likert scale ranging from 0 to 5. Accordingly, the content validity ratio and the content validity index were used to evaluate content validity. Lawshe's ratio was used to calculate the content validity ratio. For this purpose, the objectives of the protocol were initially explained to the specialists, who were then asked to classify each content item using a three-category scale: "essential," "useful but not essential," and "not essential." Their responses were subsequently converted into content validity ratio values. In this study, the minimum acceptable content validity ratio was 0.49. To calculate the content validity index, the specialists were asked to determine the relevance of each item using a four-category scale: "not relevant," "requires major revision," "relevant but requires revision," and "completely relevant." A value greater than 0.79 for each component was considered acceptable.

In the quantitative phase, a quasi-experimental pretest–posttest design with a control group was used. The statistical population consisted of third-, fourth-, and fifth-grade elementary school students in Tabriz who had attended psychological centers and received a diagnosis of dyslexia. Among these students, 30 were selected through convenience sampling and randomly assigned to an experimental group and a control group, with 15 students in each group. First, the Wechsler Intelligence Scale was administered to both groups to ensure that the participants had intelligence quotients within the normal range. The d2 Test, N-back Test, and Stroop Test were then administered to both groups as pretests. After the experimental group completed 15 intervention sessions, each lasting 45 minutes, the d2 Test, N-back Test, and Stroop Test were administered again to both the experimental and control groups as posttests. All research data were collected from June 2024 to February 2026.

The inclusion criteria were a diagnosis of dyslexia, enrollment in the third, fourth, or fifth grade, nonparticipation in concurrent therapeutic interventions, and informed consent from both the parents and the child. The exclusion criteria were absence from more than three intervention sessions, parental unwillingness to continue the intervention process, the child's lack of cooperation during the sessions, and participation in other concurrent intervention programs.

In this study, the participants' personal information and privacy were protected, and all forms of discrimination among participants were avoided. The participants took part in the study voluntarily and with adequate awareness of the research procedures, and they were free to withdraw from the study at any time. Upon request, the study findings were made available to the participants. The findings were not inconsistent with the social, cultural, or religious values of the community and were reported honestly, comprehensively, and accurately. The principal objective of the study was to promote human health.

2.2. Measures

2.2.1. d2 Test of Attention

The d2 Test, which is used to assess attention, mental effort, error rate or accuracy, and concentration in children, was developed by Brickenkamp (2002). It is currently regarded as one of the most widely recognized and precise instruments for assessing attention and mental effort internationally. The test yields three scores. The first is the total performance score (GZ), which is regarded as an indicator of the participant's information-processing speed. The second is the error score (F), which represents the participant's total number of errors. Brickenkamp identified this score as an indicator of mental effort and accuracy. The third is the concentration performance score (KL). Cronbach's alpha and test–retest reliability coefficients for the German and English versions have been reported to range from 0.90 to 0.98. The test was standardized by Bagheri in 2011, and its validity was confirmed (Bagheri, 2011). In the present study, a reliability coefficient of 0.87 was obtained.

2.2.2. Stroop Color–Word Test

The Stroop Test was developed by Ridley Stroop in 1905 to assess selective attention and cognitive flexibility. The computerized version of the Stroop Test was used in the present study. The test consists of the following three stages.

In the first stage, known as the congruent-trial stage, the names of four primary colors are presented in black in the center of the computer screen. The participant is required to press the blue, red, yellow, or green key on the keyboard as quickly as possible according to the name of the displayed color.

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In the second stage, the names of the four primary colors are displayed in the center of the screen, with each word printed in its corresponding color. The participant is required to press the key corresponding to each color as quickly as possible.

In the third stage, known as the incongruent-trial or interference stage, the names of the four primary colors are displayed on the screen in colors that differ from the semantic meaning of the words. Participants are asked to press the key corresponding to the color of the word, rather than its meaning, as quickly as possible. For example, the word "red" may be presented in green ink, in which case the participant must identify the ink color rather than the semantic meaning of the word.

The indices measured by this test are accuracy, represented by the number of correct responses, and speed, represented by the reaction time for correct responses to stimuli in milliseconds (Lee et al., 2019). Uttl and Graf (1995) reported a mean validity coefficient greater than 0.75 for the three Stroop conditions. Ghadiri, Jazayeri, Oshairi, and Ghazi Tabatabaei (2006) reported test–retest reliability coefficients of 0.06, 0.83, and 0.90 for the three conditions, respectively. In the present study, reliability coefficients of 0.87 and 0.76 were calculated for reaction time and number of errors, respectively.

2.3. N-Back Working Memory Test

The N-back Test is a cognitive performance task associated with executive functions and is commonly used in neuroimaging studies to elicit brain activity. The test was first introduced by Kirchner in 1985. In the general procedure, a sequence of stimuli, usually visual stimuli, is presented to the participant one at a time. The participant must determine whether the currently presented stimulus corresponds to the stimulus presented N steps earlier. The task can be administered with different values of N, and its difficulty increases as the value of N increases. Thus, in the 1-back task, where N = 1, the most recently presented stimulus is compared with the immediately preceding stimulus. In the 3-back task, where N = 3, the most recently presented stimulus is compared with the stimulus presented three trials earlier.

Each stage of the task consists of 120 trials. Each trial includes a number displayed for 200 milliseconds, with an interval of 800 milliseconds between successive numbers. The total duration of the test in each stage is three minutes. Because this task requires both the maintenance and manipulation of cognitive information, it is considered highly appropriate for assessing working memory performance and has been widely used for this purpose in recent years (Jansma et al., 2000).

Kane et al. (2007, as cited in Taghizadeh et al., 2015) reported reliability coefficients ranging from 0.54 to 0.84, and the validity of the test as an indicator of working memory performance has been considered highly acceptable. Bush et al. (2008, as cited in Taghizadeh et al., 2015) reported a Cronbach's alpha reliability coefficient of 0.78 for the test. In Iran, Khorasani et al. (2017) reported reliability coefficients ranging from 0.54 to 0.84. In the present study, the Cronbach's alpha reliability coefficient of the test was 0.80.

2.4. Data Analysis

The data obtained from the tests were analyzed using analysis of variance in IBM SPSS Statistics, Version 26.

3. Findings and Results

To develop the content of the computerized cognitive skills package, previous studies in this field were initially reviewed. These studies and sources assisted the researchers in designing the content and exercises of each section of the computerized package on the basis of scientific evidence and credible research experience. Accordingly, Table 1 presents the objectives and content of each section of the computerized package by session. The content validity ratio and content validity index were subsequently calculated for each item.

Table 1

Protocol Content and Evaluation of the Content Validity Ratio and Content Validity Index

Sessions	Objective	Content	Method	CVR	CVI
1–2	Introduction and discussion of the general objectives of the intervention program	General information about the package and intervention program is explained to the children and their families.	Lecture	0.98	0.87
3–4	Assessment and development of phonological awareness	Phonological-awareness component of the computerized package	Implementation of the phonological-awareness	0.95	0.90

			section of the computerized package		
5–7	Assessment and instruction of letters that the participants do not recognize correctly or completely	Letter-instruction component based on the participants' difficulties or lack of letter recognition	Implementation of the letter-instruction section of the computerized package	0.99	0.94
8–10	Assessment and instruction of letter combinations using a phoneme-blending method	Implementation of the phoneme-blending section of the computerized package, with emphasis on difficulties in specific combinations	Implementation of the phoneme-blending section of the computerized package	0.99	0.95
11–13	Assessment and development of reading fluency	Reading-fluency component of the computerized package, including repetition and word practice	Implementation of the reading-fluency section of the computerized package	0.90	0.88
14–15	Assessment and development of reading comprehension	Recognition of interrogative words and explanation and answering of questions concerning the texts read, based on the reading-comprehension section of the computerized package	Implementation of the reading-comprehension section of the computerized package	0.96	0.99
16–25	Development of executive functions required for reading, including selective attention, response inhibition, and working memory, through computerized games	Games designed in the computerized package to enhance executive functions	Implementation of the computerized-games section of the package	0.98	0.95

During the validation process for the computerized cognitive skills package, the designed content was provided to 10 psychology specialists whose characteristics are presented in Table 2. The specialists evaluated each component in terms of its relevance to the program objectives and the necessity of its content using a six-point Likert scale. Content validity was calculated using two indices: the content validity ratio based on Lawshe's formula and the content validity index based on the Waltz and Bausell model. The minimum acceptable content validity ratio was 0.49. As shown in Table 1, all obtained content validity ratios were higher than this value. Furthermore, because the content validity index for every component was higher than 0.79, no component was removed. It can therefore be stated that the designed computerized package had satisfactory content validity.

Table 2

Characteristics of the Specialists

No.	Area of Specialization	Academic Degree	Age
1	Psychology and Education of Exceptional Children	PhD	52
2	Educational Psychology	PhD	60
3	Psychology and Education of Exceptional Children	PhD	45
4	Psychology and Education of Exceptional Children	PhD	55
5	Educational Psychology	PhD	42
6	Psychology and Education of Exceptional Children	PhD	67
7	Educational Psychology	PhD	58
8	Psychology and Education of Exceptional Children	PhD	40
9	Educational Psychology	PhD	59
10	Educational Psychology	PhD	41

The data obtained from the experimental and control groups were also summarized using descriptive statistics, and the corresponding information is presented below. In the inferential-statistics section, the research hypotheses were tested and the results were interpreted. Table 3 presents the descriptive statistics for the selective attention, response inhibition, and working memory scores of the participants in the experimental and control groups at the pretest and posttest stages.

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Table 3

Descriptive Statistics for Selective Attention, Response Inhibition, and Working Memory Scores in the Experimental and Control Groups

Variable	Group	n	Pretest Mean	Pretest SD	Posttest Mean	Posttest SD
Selective attention	Experimental	15	229.87	7.03	379.00	11.66
	Control	15	229.47	7.40	235.40	7.61
Response inhibition	Experimental	15	3.536	0.84	0.515	0.10
	Control	15	3.533	0.78	3.374	0.60
Working memory	Experimental	15	108.80	7.46	147.40	6.59
	Control	15	107.27	6.61	108.87	6.85

According to the information presented in Table 3, the mean selective-attention scores of the experimental group at pretest, control group at pretest, experimental group at posttest, and control group at posttest were 229.87, 229.47, 379.00, and 235.40, respectively. These values indicate only a slight difference between the pretest scores of the experimental and control groups but a substantial difference between their posttest scores.

For response inhibition, the mean scores of the experimental group at pretest, control group at pretest, experimental group at posttest, and control group at posttest were 3.536, 3.533, 0.515, and 3.374, respectively. These results indicate only a slight difference between the pretest scores of the experimental and control groups but a substantial difference between their posttest scores.

For working memory, the mean scores of the experimental group at pretest, control group at pretest, experimental group at posttest, and control group at posttest were 108.80, 107.27, 147.40, and 108.87, respectively. These values indicate only a slight difference between the pretest scores of the experimental and control groups but a substantial difference between their posttest scores.

Analysis of variance was used to determine the statistical significance of the observed differences between the experimental and control groups. Before conducting the principal analysis, the Kolmogorov–Smirnov test was used to examine the relevant statistical assumption. The results supported the assumption of homogeneity of variance ($p > .05$). Table 4 reports the results of the one-way analysis of variance conducted to examine differences between the experimental and control groups in posttest selective attention, response inhibition, and working memory scores.

Table 4

Results of the Analysis of Variance for Posttest Selective Attention, Response Inhibition, and Working Memory Scores in the Experimental and Control Groups

Variable	df	*F*	*p*
Selective attention	1	1594.63	< .001
Response inhibition	1	327.49	< .001
Working memory	1	286.24	< .001

The results presented in Table 4 show that the significance levels for differences between the experimental and control groups in selective attention, response inhibition, and working memory were below the predetermined significance threshold ($p < .001$). Therefore, the differences between the experimental and control groups in selective attention, response inhibition, and working memory were statistically significant. More specifically, children with dyslexia who used the designed computerized package demonstrated improvements in selective attention, response inhibition, and working memory. Consequently, the designed computerized package was effective in enhancing selective attention, response inhibition, and working memory among children with dyslexia.

4. Discussion

The present study aimed to develop a computerized cognitive skills package and examine its effectiveness in improving selective attention, response inhibition, and working memory among children with dyslexia. The findings demonstrated statistically significant differences between the experimental and control groups in all three

E-ISSN: 3060-6713

cognitive outcomes at posttest. More specifically, children with dyslexia who participated in the computerized intervention exhibited a substantial improvement in selective attention, a marked reduction in response-inhibition errors or response latency, and a meaningful increase in working-memory performance compared with children in the control group. These results indicate that the developed package was effective in strengthening the executive processes that support reading and academic performance. The findings are consistent with contemporary conceptualizations of dyslexia as a multidimensional learning disorder involving not only phonological and decoding impairments but also weaknesses in attentional control, inhibitory regulation, memory updating, and other executive functions (American Psychiatric, 2023; Horowitz-Kraus et al., 2026). From this perspective, the effectiveness of the intervention may be attributed to its integrated structure, which combined reading-related activities, including phonological awareness, letter recognition, phoneme blending, reading fluency, and comprehension, with computerized exercises targeting selective attention, response inhibition, and working memory.

The first major finding showed that the computerized cognitive skills package significantly improved selective attention among children with dyslexia. This result is theoretically plausible because selective attention enables children to prioritize relevant visual and linguistic information while suppressing distracting stimuli. During reading, children are required to identify target letters, distinguish visually similar symbols, maintain their focus across lines of text, and avoid interference from adjacent words and environmental distractions. Children with dyslexia may experience difficulty allocating visual attention efficiently, which can disrupt letter identification, word recognition, and reading fluency. Previous research has shown that students with reading-related specific learning disorders perform more poorly than their typically developing peers in selective attention and other executive processes (Amani et al., 2018). A scoping review also found that children with dyslexia frequently demonstrate atypical visual selective-attention and visual-search performance, indicating that attentional inefficiency may contribute directly to reading difficulties (Hokken et al., 2023). Neurophysiological evidence similarly suggests that children with dyslexia show atypical neural responses during the selection of relevant visual stimuli and the suppression of distractors (Liu et al., 2024). Therefore, the improvement observed in the present study may reflect enhanced attentional allocation, more efficient filtering of irrelevant information, and greater stability of focus during cognitively demanding tasks.

The selective-attention finding is also consistent with intervention studies demonstrating that computerized cognitive rehabilitation and game-based exercises can improve attentional functioning. Computerized cognitive rehabilitation has been shown to enhance selective attention and executive functions among students with attention-deficit/hyperactivity disorder (Kamarzarin et al., 2019), while the Aram cognitive rehabilitation package has improved executive functioning among preschool children with symptoms of that disorder (Maghsoudlou et al., 2019). Cognitive games have similarly produced improvements in attention among students with dyscalculia, suggesting that the benefits of game-based cognitive training can extend across different learning-disorder populations (Arjmandnia et al., 2018). In students with dyslexia, the Captain's Log computerized cognitive rehabilitation program has been reported to improve both reading performance and executive functions (Shamshiri et al., 2024). Comparative investigations have likewise shown that computerized cognitive rehabilitation can improve executive-function outcomes in students with dyslexia (D. Shamshiri et al., 2025; M. Shamshiri et al., 2025; Mina Shamshiri et al., 2025). These consistent findings support the proposition that repeated practice in computerized environments can progressively strengthen the child's ability to attend to relevant stimuli, sustain concentration, and control attentional shifts.

Several mechanisms may explain the effect of the intervention on selective attention. First, the computerized format enabled the systematic presentation of stimuli with controlled timing, repetition, and difficulty. Such standardization may help children gradually become more accurate and efficient in detecting relevant stimuli. Second, immediate feedback may have facilitated error recognition and encouraged the modification of ineffective response patterns. Third, game-based exercises may have increased engagement and reduced the fatigue often associated with conventional remedial instruction. Serious games have been identified as promising tools for strengthening executive functions in neurodiverse children because they combine therapeutic goals with interactive, adaptive, and motivating activities (Rodriguez Timana et al., 2024). Video-game training has also been associated with improvements in selective attention, demonstrating that repeated interaction with cognitively demanding digital environments can modify attention-related performance (Ballesteros et al., 2017). The current package may therefore have enhanced selective attention by providing repeated opportunities to identify targets, suppress irrelevant visual information, and respond within increasingly demanding conditions.

The second major finding indicated that the computerized cognitive skills package significantly improved response inhibition. Response inhibition allows an individual to suppress dominant, automatic, impulsive, or inappropriate responses and replace them with responses that are more consistent with task demands. In reading, inhibitory control is essential because children must avoid guessing words prematurely, inhibit incorrect phonological responses, disregard irrelevant word features, and correct an initial interpretation when it conflicts with subsequent information. Weak inhibition can lead to impulsive word recognition, repeated reading errors, poor self-monitoring, and difficulty following instructional rules. The significant reduction in response-inhibition difficulties in the experimental group suggests that the intervention strengthened the children's ability to pause, evaluate stimuli, and select contextually appropriate responses rather than acting automatically.

This finding is aligned with previous research on cognitive rehabilitation and game-based executive-function interventions. Computerized working-memory interventions have improved response control among students with specific learning disorders (Khaksar Boldaji et al., 2018). Cognitive games have also been found to enhance response inhibition in children with dyscalculia (Arjmandnia et al., 2018). Research on strategy games suggests that games requiring planning, rule maintenance, and response selection can influence inhibitory control (Leong et al., 2022). Inhibitory control has also been shown to be modifiable through structured classroom-based activities in young children (Lambert, 2021). Moreover, the positive effects of computerized cognitive rehabilitation on executive functions among children with dyslexia reported in earlier studies support the present results (Mina Shamshiri et al., 2025; Shamshiri et al., 2024). The current findings therefore contribute to a growing body of evidence indicating that response inhibition is not a fixed deficit but a trainable executive capacity.

The effect on response inhibition may have resulted from several characteristics of the intervention. Many computerized tasks require participants to delay responding until all relevant information has been processed, distinguish target from nontarget stimuli, follow changing rules, and suppress responses when a stimulus does not meet predefined criteria. Repeated engagement with these demands may strengthen top-down cognitive control and improve the balance between response speed and accuracy. The inclusion of reading and phonological exercises may also have increased the ecological relevance of the training, because children were required to inhibit incorrect letter, sound, or word associations within educationally meaningful tasks. Executive functions operate interdependently, and improvements in attention may have contributed to better inhibitory performance by enabling children to detect relevant cues before responding. The relationship between cognitive and behavioral regulation is also supported by evidence showing that executive functions contribute to broader patterns of self-regulated behavior (Gray-Burrows et al., 2019). Accordingly, the improved inhibitory performance observed in the present study may reflect not only greater control over motor responses but also enhanced monitoring, attentional stability, and strategic decision making.

The third major finding demonstrated a significant improvement in working memory among children who received the computerized intervention. Working memory is essential for temporarily maintaining and manipulating information while completing a task. During reading, it allows children to retain letter–sound correspondences, blend phonemes, remember previously decoded words, connect successive parts of a sentence, and integrate new information with earlier content. A child with limited working-memory capacity may recognize individual words but fail to maintain sufficient information to understand a complete sentence or passage. The observed increase in N-back performance suggests that the computerized package improved the children's capacity to update, maintain, and manipulate cognitive information over short periods.

This result is consistent with research demonstrating the effectiveness of working-memory interventions in children with reading difficulties. Working-memory training has been found to improve performance among students with reading-comprehension difficulties (Novaes et al., 2019). Cognitive rehabilitation has also enhanced working memory and verbal fluency in students with dyslexia (Farhad et al., 2016). Furthermore, computerized cognitive educational interventions targeting working memory have improved attention, response control, and the central executive component of working memory among students with specific learning disorders (Khaksar Boldaji et al., 2018). Attention-memory training has yielded both behavioral and academic improvements in children with attention-deficit/hyperactivity disorder and comorbid learning disorders (Carlos Farias et al., 2017). These findings indicate that working-memory training may influence not only performance on cognitive tasks but also functional educational outcomes.

The effectiveness of the intervention for working memory may be explained by the repeated requirement to encode, retain, update, and retrieve information during the computerized exercises. The N-back and related cognitive tasks require continuous comparison between current and previously presented stimuli and therefore place direct demands on memory updating. The package's phonological-awareness and phoneme-blending components may also have strengthened the phonological subsystem of working memory. When children repeatedly hold individual sounds in mind and combine them to form words, they practice both short-term retention and mental manipulation. Similarly, reading-fluency and comprehension exercises require the maintenance of previously processed words and sentences while integrating subsequent information. As a result, the intervention may have supported both domain-general working memory and reading-specific memory processes. The systematic review of cognitive approaches to dyslexia emphasizes that effective interventions should address the interaction of multiple cognitive systems rather than focusing narrowly on a single deficit (Akyurek et al., 2024). The integrated structure of the present package appears consistent with this recommendation.

The simultaneous improvement in selective attention, response inhibition, and working memory is particularly important because these processes are mutually reinforcing rather than independent. Selective attention ensures that relevant information enters the cognitive system, response inhibition prevents competing information or impulsive responses from disrupting processing, and working memory maintains and manipulates selected information to guide behavior. A weakness in any one component can reduce the efficiency of the others. For example, poor attentional filtering may overload working memory with irrelevant information, while weak inhibition may permit distracting or incorrect responses to dominate task performance. Developmental cognitive neuroscience increasingly emphasizes the interaction between executive functions and learning disabilities across reading, mathematics, and attention-related disorders (Horowitz-Kraus et al., 2026). The present findings support this interactive account by showing that a comprehensive intervention can generate improvements across multiple executive domains.

The results also reinforce the value of computerized cognitive rehabilitation as an adjunct to conventional instruction for children with dyslexia. Computerized programs can provide high-intensity practice, immediate feedback, precise control of stimulus presentation, and individualized progression. They may be especially helpful for children who lose motivation during repetitive traditional exercises. A systematic review of computerized cognitive training in children and adolescents with neurodevelopmental disorders reported promising effects on selected cognitive functions, although outcomes depended on intervention design and dosage (Lin et al., 2025). Similarly, research on serious games has highlighted the potential of interactive technologies to enhance executive functions in neurodiverse children (Rodriguez Timana et al., 2024). The current study extends these findings by demonstrating that a package developed through literature review, examination of existing programs, needs assessment, and expert validation can improve several executive functions in children with dyslexia.

The findings may also be understood in relation to neuroplasticity. Repeated activation of cognitive networks through progressively challenging tasks may increase the efficiency of the neural systems responsible for attention, inhibition, and working memory. Cognitive rehabilitation research in clinical populations has demonstrated that structured cognitive exercises can support functional recovery and improve cognitive performance (Bergo et al., 2016). Although developmental dyslexia differs from acquired neurological conditions, both forms of intervention rely on experience-dependent modification of cognitive systems. Repetition, graded difficulty, feedback, and active engagement may strengthen existing neural pathways and facilitate the development of compensatory strategies. In children, whose cognitive and neural systems are still developing, such training may be particularly effective when implemented during the elementary-school years.

The present findings are additionally supported by studies showing that cognitive rehabilitation can reduce cognitive failures in students with learning disabilities (Abbariki et al., 2017) and improve academic achievement among students with dyslexia (Shakeri Chenari et al., 2026). These results suggest that gains in executive functions may have consequences beyond the specific cognitive measures used in the study. Improved selective attention may enable children to remain engaged during instruction; stronger inhibition may reduce impulsive errors; and enhanced working memory may support reading comprehension,

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classroom learning, and completion of multistep tasks. Although the current study primarily measured cognitive outcomes, the structure of the package suggests that its benefits may eventually transfer to broader educational functioning. Nevertheless, such transfer should be directly assessed in future investigations rather than assumed.

The validity of the intervention package represents another important aspect of the study. The content was developed from multiple sources, including previous research, existing computerized packages, and the needs of children with dyslexia, and was subsequently evaluated through expert consensus. All content validity ratio and content validity index values exceeded the established thresholds, indicating that specialists considered the components relevant and necessary. This systematic development process may have contributed to the intervention's effectiveness because the activities were aligned with both theoretical principles and practical needs. The inclusion of phonological awareness, letter instruction, phoneme blending, reading fluency, reading comprehension, and executive-function games created a comprehensive sequence that addressed both fundamental reading skills and supporting cognitive mechanisms. This is important because educational experiences and the accessibility of instructional environments can substantially affect students with specific learning difficulties (Podsiadlik, 2023). A culturally and developmentally adapted intervention may therefore be more engaging and relevant than a generic or imported program.

5. Conclusion

The findings of the present study demonstrated that the developed computerized cognitive skills package was effective in improving selective attention, response inhibition, and working memory in children with dyslexia. The significant posttest differences between the experimental and control groups indicate that a structured intervention combining reading-related components with targeted computerized cognitive exercises can strengthen the executive processes that support accurate, fluent, and purposeful reading. By integrating phonological awareness, letter recognition, phoneme blending, reading fluency, reading comprehension, and executive-function games, the package addressed both the direct academic manifestations of dyslexia and the underlying cognitive weaknesses associated with it. Therefore, this intervention may be considered a useful complementary approach for educational psychologists, special-education professionals, and rehabilitation practitioners working with children with dyslexia, particularly when conventional reading instruction alone does not adequately address deficits in attention, inhibitory control, and working memory.

The present study had several limitations that should be considered when interpreting its findings. The sample consisted of only 30 third-, fourth-, and fifth-grade students with dyslexia from psychological centers in Tabriz, and the participants were selected through convenience sampling; therefore, the generalizability of the findings to children from other regions, educational systems, socioeconomic backgrounds, age groups, or levels of reading impairment is limited. The relatively small sample size may also have increased the influence of individual differences and reduced the precision of the estimated intervention effects. The study used a pretest–posttest design without a follow-up assessment, and consequently it was not possible to determine whether improvements in selective attention, response inhibition, and working memory were maintained over time. The control group did not receive an active alternative intervention, making it difficult to separate the specific effects of the computerized cognitive content from nonspecific factors such as increased attention from researchers, novelty, motivation, and contact time. The study relied primarily on performance-based cognitive measures and did not assess the transfer of improvements to reading accuracy, reading fluency, comprehension, classroom behavior, academic achievement, or everyday executive functioning. In addition, factors such as prior exposure to digital games, home computer access, medication use, comorbid attention difficulties, and family educational support were not systematically controlled.

Future studies should replicate the investigation with larger and more diverse samples recruited through probability-based or multicenter sampling procedures. Randomized controlled trials involving active comparison groups would provide stronger evidence regarding the specific effectiveness of the computerized package. Researchers should include follow-up assessments at intervals such as three, six, and twelve months to determine the durability of treatment gains. Future investigations should also evaluate whether improvements in executive functions transfer to reading accuracy, phonological decoding, reading fluency, spelling, reading comprehension, academic achievement, and classroom functioning. It would be valuable to compare different intervention dosages, session durations, difficulty-progression systems, and

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combinations of computerized training with direct reading instruction. The moderating roles of age, sex, initial severity of dyslexia, intelligence, comorbid attention problems, motivation, and previous digital experience should also be examined. Neurophysiological and eye-tracking measures could be used to clarify the mechanisms through which training influences attentional allocation, inhibitory control, and working-memory updating. Qualitative interviews with children, parents, and teachers may further identify which components are most engaging, accessible, and applicable to everyday educational settings.

Educational psychologists, special-education teachers, school counselors, and rehabilitation professionals may use the developed computerized package as a complementary intervention for children with dyslexia, particularly when difficulties in reading coexist with weaknesses in selective attention, response inhibition, and working memory. The package should be implemented under professional supervision, with the level of difficulty adjusted to each child's cognitive and reading abilities. Practitioners should combine computerized exercises with explicit instruction in phonological awareness, decoding, fluency, and reading comprehension rather than treating cognitive training as a substitute for evidence-based reading instruction. Progress should be monitored through repeated cognitive and academic assessments, and the training program should be modified when a child shows fatigue, frustration, or limited improvement. Schools may integrate brief computerized sessions into individualized educational programs, provided that adequate equipment, quiet spaces, and trained personnel are available. Parents can also be instructed on how to support consistent practice at home without increasing academic pressure. Coordination among families, teachers, and clinicians is recommended to facilitate the transfer of cognitive gains to reading activities, classroom participation, and everyday learning tasks.

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.

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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