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# The Effects of Digital Psychoeducational Interventions on the Verbal Fluency of Students with Dyslexia and Dysgraphia

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This study aimed to examine the effects of digital psychoeducational interventions on the verbal fluency of students diagnosed with dyslexia and dysgraphia. The research employed a quasi-experimental design with a pretest-posttest control group. The study sample comprised children aged 10 to 12 years with diagnosed dyslexia and dysgraphia, who were selected via convenience sampling from services centers for children with learning disorder in District 4 of Karaj City during the 2020–2021 academic year. Participants were subsequently randomized into experimental and control groups, with 15 individuals allocated to each. The experimental group received individualized cognitive training consisting of twelve 35–40-minute sessions using Captain's Log software. Psychoeducational intervention was not offered to the control group in this study. The Wechsler Intelligence Scale for Children (WISC-IV) was employed to assess general cognitive ability. In addition, the NEMA Reading and Dyslexia Test and Fallah Chay's Dysgraphia Test were administered to diagnose dyslexia and dysgraphia, respectively. Verbal fluency was evaluated pre- and post-intervention employing standardized verbal fluency tests. Analysis of covariance was conducted in its univariate (ANCOVA) and multivariate (MANCOVA) forms utilizing SPSS version 24 to analyze the data. Results indicated a significant positive effect of digital psychoeducational interventions on semantic fluency (p = .0001) and phonemic fluency (p = .004). Findings suggest that digital psychoeducational programs can enhance verbal fluency in students with dyslexia and dysgraphia.

***Keywords:*** Dyslexia, Dysgraphia, Verbal fluency, Digital psychoeducational interventions.

Learning is a fundamental psychological concept and has been extensively investigated in numerous studies. The ability to learn significantly impacts academic performance and, by extension, an individual's social functioning (Lucas, 2019). Specific learning disorders (SLDs) have recently increased substantially, drawing growing attention from educational specialists, psychologists, and policymakers (Afeli, 2019). The contributing factors, mechanisms, and outcomes of specific learning disorders (SLDs) remain subjects of scholarly debate, with numerous theoretical frameworks proposing divergent and occasionally contradictory explanations. Peters et al. (2018) contend that, although the overarching notion of Specific Learning Disorder (SLD) is broadly acknowledged, its precise definitional boundaries remain multifaceted and the subject of ongoing scholarly contest.

The latent and often subtle nature of SLD symptoms complicates their detailed and in-depth investigation (Xin et al., 2020). Originally conceptualized within the medical field, learning disorders retain traces of their medicalized definitions and classifications, which continue to shape both diagnostic and intervention approaches (Power & Bartlett, 2019). Over time, psychological and cognitive theories have profoundly influenced definitions of SLDs, as well as the understanding of their etiology and treatment (Zhang et al., 2020). According to the Diagnostic and Statistical Manual of Mental Disorders (DSM-5), SLDs are neurodevelopmental disorders of biological origin, associated with cognitive abnormalities that manifest behaviorally and impair efficient processing of verbal and non-verbal information (American Psychiatric Association, 2013). Children with SLDs perform significantly below expectations for their age, intelligence, and educational level, exhibiting persistent impairments in skills such as reading fluency, comprehension, spelling, and mathematical reasoning (Mariño et al., 2018). Notably, these impairments are not attributable to sensory, motor, or intellectual disabilities, nor to emotional disturbances or adverse environmental, cultural, or economic factors (Zhang et al., 2019).

Among SLDs, dyslexia and dysgraphia are among the most common, typically characterized by persistent difficulties with spelling, word recognition, decoding, and fluency in reading and writing (American Psychiatric Association, 2013). Cognitive theories attribute these difficulties primarily to deficits in neuropsychological processes, particularly executive functions such as working memory, attention, and processing speed (Reid, 2016). Indeed, neuropsychological research confirms that children with dyslexia and dysgraphia often exhibit impaired performance on measures of executive function (Hallahan et al., 2013). One such key domain of executive function, and the focus of the present study, is verbal fluency, which refers to the ability to retrieve and generate appropriate words efficiently within semantic or phonemic constraints (Aita et al., 2019).

Verbal fluency has long stood as a central facet of neuropsychological assessment, reflecting its dependence on an array of executive processes that coordinate lexical retrieval, lexical-semantic organization, response selection, and cognitive control. Deficits in verbal fluency are widely observed in individuals with psychiatric disorders, brain injuries, and notably, children with learning disabilities (Basagni et al., 2017). Verbal fluency competence encompasses the capacity for rapid word retrieval, vocabulary development, and the flexible production of novel verbal responses. It is commonly categorized into semantic and phonemic fluency (Cahyaningrum et al., 2023). These abilities depend critically on executive functions such as working memory, attention control, and cognitive flexibility, which support the efficient organization and retrieval of lexical items (Smith-Spark & Gordon, 2022). Research indicates that children with learning disabilities often exhibit restricted vocabularies, characterized by a skew toward high-frequency, short words, accompanied by semantic deficits such as weak category knowledge and impaired word classification skills (Kim & Petscher, 2023).

Recent research by Kanniainen (2023) further corroborates that semantic verbal fluency in dyslexic learners is particularly sensitive to interventions targeting executive control. Studies also underscore the central role of phonological processing deficits in the reading and writing challenges experienced by these children (Goldstein et al., 2019). For example, Mahrooghi et al.'s (2020) study on dyslexic students demonstrated that cognitive rehabilitation focused on attention and working memory improved both verbal fluency and processing speed. Similarly, Zellner et al. (2024) recently highlighted that targeted digital exercises significantly enhance word retrieval and verbal fluency in children with SLDs. Therefore, considering that the disruption of neuropsychological functions plays a role in children's reading and writing disorders, it can be concluded that the rehabilitation of the functions involved in dyslexia-miswriting is efficacious in improving reading and writing disorders.

Children with dyslexia frequently exhibit word retrieval difficulties, displaying pronounced deficits in verbal fluency relative to their typically developing peers (Weckerly et al., 2001). Beyond psychiatric and neurological conditions, various demographic factors—including age, gender, and educational attainment—have been found to influence verbal fluency performance (Formank et al., 2019). Recent technological advancements have stirred interest in alternative educational environments, particularly multimedia-based learning systems, which enhance learning outcomes across diverse disciplines (Cheng, 2021). Digital psychoeducational interventions integrate visual-auditory, sensory-motor, and behavioral-educational techniques, utilizing language-based, written, and activity-driven approaches to foster adaptive behaviors and promote independence in children with learning disabilities. These interventions modulate neural processing functions, leading to measurable improvements in perceptual skills, attention, memory, problem-solving, behavioral regulation, and academic competencies such as reading, writing, and mathematics (Sohlberg & Mateer, 2017).

Empirical evidence supports the efficacy of technology-assisted learning in addressing dyslexia-related challenges. Jing and Chen (2017) assert that digital tools—including educational games, virtual learning environments, text-to-speech (TTS) systems, and interactive e-books—can enhance reading fluency, comprehension, and error reduction. Such interventions increase engagement, sustain attention through multimedia elements, and provide an enjoyable learning experience (Yaacob et al., 2024; Hussain et al., 2023; Maresca et al., 2022; Jaramillo-Alcázar et al., 2021). While some studies note that digital learning may reduce tactile sensory input (Bakar, 2023), it concurrently extends attentional capacity, enabling greater cognitive input for dyslexic learners and thereby improving reading proficiency.

The rise of digital learning platforms has underscored their potential to enhance cognitive and educational outcomes, particularly for individuals with special needs. Interactive multimedia environments engage learners through visual, auditory, and kinesthetic modalities, addressing limitations inherent in traditional, static instructional methods (Çeken & Taşkın, 2022). Digital psychoeducational interventions, with their adaptive, gamified, and multisensory components, are particularly effective in targeting executive function deficits in learners with dyslexia and dysgraphia (Boivin et al., 2016).

Mayer et al. (2019) demonstrated that video-game-based cognitive training enhances attention, working memory, and reasoning. Basharpoor et al. (2024) and Alali et al. (2024) have found that digital interventions enhance semantic and phonemic fluency in children with dyslexia and bolster narrative skills in those with dysgraphia. According to studies, digital interventions are effective in improving executive functions (Boivin et al., 2016; Mayer et al, 2019). However, there are few studies on executive functions (verbal fluency) in children with dyslexia and dysgraphia. Given the high prevalence of learning disorders and the imperative to remediate cognitive deficits in affected children, and considering that reading and writing are foundational academic skills that are interrelated and essential in daily life, coupled with the existing gap in this domain, this study aims to evaluate the effectiveness of digital psychoeducational interventions in enhancing verbal fluency among children with dyslexia and dysgraphia.

Therefore, the present research has strived to answer the question of whether the use of digital psychoeducational interventions enhances the verbal fluency of students with dyslexia and dysgraphia.

## Method

The participants of the present study consisted of 30 students (boys and girls) aged 10 to 12 years who had been formally diagnosed with dyslexia and dysgraphia. Participants were selected through convenience sampling from learning disorder service centers located in District 4 of Karaj City during the 2020–2021 academic year. Following selection, participants were randomly assigned to either the experimental group (n = 15) or the control group (n = 15).

In terms of gender distribution, both male and female students were included in the study, and efforts were made to ensure a relatively balanced gender composition across the two groups. All participants were enrolled in public elementary schools and were attending grades four to six at the time of the study.

The inclusion criteria were: (a) age range between 10 and 12 years, (b) a formal diagnosis of dyslexia and dysgraphia based on the NEMA Reading and Dyslexia Test and Fallah Chay's Dysgraphia Test, (c) an intelligence quotient (IQ) within the normal range as assessed by the Wechsler Intelligence Scale for Children–Fourth Edition (WISC-IV), (d) absence of sensory impairments (e.g., uncorrected visual or auditory deficits), neurological disorders, or major psychiatric conditions, and (e) no prior participation in structured cognitive or psychoeducational intervention programs during the previous six months.

Exclusion criteria included irregular attendance in intervention sessions, lack of cooperation during assessment or training sessions, and withdrawal of parental consent at any stage of the study.

Parental educational level and socioeconomic status were recorded using a demographic questionnaire completed by parents. The majority of participants came from families with middle socioeconomic status, and parents' educational levels ranged from secondary education to university degrees. No statistically significant differences were observed between the experimental and control groups with respect to age, gender distribution, IQ scores, or parental socioeconomic status at baseline.

## Instruments

### Verbal Fluency Test

The Verbal Fluency Test was first introduced by Thurstone (1938) to evaluate verbal retrieval and executive functions. It comprises two subscales: semantic and phonemic fluency (Khatoonabadi et al., 2021).

### Phonemic fluency

The subscale includes three Persian letters (ج ,ف ,پ). Each letter is displayed on a card and read aloud by the examiner. Participants are asked to generate as many words as possible starting with each letter within one minute. Repeated or mispronounced words receive zero. The total score is the sum of scores across letters, ranging from 0 to 180 (Kazemi et al., 2017).

### Semantic fluency

The subscale consists of three categories: animals, fruits, and supermarket items. For each category, participants name as many items as possible in one minute. Repetitions and incorrect words are not scored. The total score ranges from 0 to 120 (Kazemi et al., 2017).

The Persian lexical access assessment package reported a content validity coefficient of .78 and Cronbach's alpha of .78 (Ghoreishi et al., 2014). Face validity was evaluated by ten experts, with 80% agreement indicating that the test accurately measures verbal fluency. Overall reliability, as measured by Cronbach's alpha, was 0.86, indicating high internal consistency.

### Reading and Dyslexia Test (NEMA)

The NEMA test was developed by Kormi Nouri and Moradi (2005) to assess reading performance and diagnose dyslexia in children. It was standardized on 1,614 students (770 boys, 844 girls) from grades 1–5 across Tehran, Sanandaj, and Tabriz.

The test includes ten subscales, each scored by the number of correct responses:

1. **Reading words**: Three 40-word lists read quickly and accurately.
2. **Word chain**: Identify meaningful words from a list.

3. **Rhyme test**: Identify rhyming words from a 20-word list.
4. **Naming pictures**: Name objects in two sets of 20 images.
5. **Text comprehension**: Answer questions after listening to two short texts.
6. **Word comprehension**: Answer questions about the meaning or function of 30 words.
7. **Phoneme deletion**: Pronounce words after removing a target phoneme (30 words).
8. **Reading non-words**: Read 40 meaningless words correctly.
9. **Letter symbols**: Select words starting with a specific letter.
10. **Category sign:** Classify words into semantic categories (Hosseini, 2016; Kormi Nouri, 2005).

Cronbach's alpha ranged from 0.67 to 0.98 across subscales. Exploratory factor analysis explained 62% of the variance, confirming construct validity. The test is administered individually, and raw scores are converted to standard scores based on age and grade norms.

**Fallah Chay's Dysgraphia Test**

Developed by Fallah Chay (1995), this test evaluates writing ability in students with dysgraphia. It comprises two passages: the first accounts for 50% of the elementary Persian textbook, while the second passage encompasses the entire content of the textbook. Participants write each passage, and performance is scored based on accuracy and completeness. Content validity and internal consistency reliability were reported by Fallah Chay, supporting the instrument's application for assessing dysgraphia severity in elementary students.

**Wechsler Intelligence Scale for Children – Fourth Edition (WMS-IV)**

The WMS-IV (Wechsler, 2003) is a widely used intelligence scale for children aged 6–16 years 11 months. It evaluates five indices: Verbal Comprehension, Perceptual Reasoning, Working Memory, Processing Speed, and Full-Scale IQ, through 15 subtests. The Persian version was adapted and standardized by Abedi et al., (2015). Cronbach's alpha coefficients ranged from .65 to .94, and split-half reliability ranged from .76 to .91, ensuring that differences in study outcomes reflect the intervention rather than general cognitive ability.

**Implementation method**

The researchers collected the data by visiting selected centers according to a pre-specified plan, after establishing the research sample, obtaining necessary permits, and coordinating with the relevant authorities. Participants were initially identified through purposive sampling. Then, briefings were held for parents of students to explain the research objectives, following which they signed written consent forms for their children's participation in the research. The ethical considerations encompass obtaining informed consent from parents, the participants' right to withdraw at any time, assurances of confidentiality, prioritization of participants' psychological well-being, the unbiased publication of findings, adherence to principles of trustworthiness, and the citation of credible sources. The participants were randomly assigned to two groups: an experimental group receiving Captain Log's cognitive software and a control group. Then, the verbal fluency test (semantic and phonemic verbal fluency) was used as a pre-test for both groups, and their scores were recorded. After the pre-test, Captain's Log cognitive software was implemented for the experimental group. A total of 12 games were selected from the cognitive domains contained within this software, focusing on domains related to reinforcing the dependent variables of verbal fluency (attention and memory). Each game was tailored for individual participants by adjusting the level of difficulty, playing duration, and age-appropriate content. Each participant practiced every other day (three sessions per week) for 35 to 40 minutes. During the course of the study, general introductory explanations were provided at the outset of each session. However, given that the software operated in English and the prompts (e.g., "click on the red apple") were posed in English, participants who were not fluent in English required direct practice and supervision to ensure accurate comprehension and task performance. Since some participants got tired, a reward was given every 3 sessions to strengthen and increase their cooperation. What the participant did was saved in each session, and the continuation of that game was played in the next session. The control group did not receive any therapeutic intervention. After completion of the treatment sessions, the experimental and control groups were re-measured using the verbal fluency test. The following table presents a summary of the content of Captain's Log cognitive software therapy sessions.

**Table 1**
**Educational Protocol based on Captain's Log software (2022)**

| Session | Focus/Goals | Content & Activities |
|---|---|---|
| 1 | Introduction: selective attention | Target Practice, Matchmaker, Happy Trails; optional recreational game if tired |
| 2 | Sustained attention | Mouse Hunt, The Great Hunt, Pop-N-Zap; optional recreational game |

| | | |
|---|---|---|
| 3 | General attention | Where is My Car? Tricky Tracks, Great Escape, Darts; optional recreational game |
| 4 | Immediate & working memory | Racing Robots, Domino Dynamite, Code Cracker, Eureka; optional recreational game |
| 5 | Selective attention (higher level) | Increased difficulty; system feedback determines advancement or repeat |
| 6 | Sustained attention (higher level) | Increased difficulty, system feedback; optional recreational game |
| 7 | General attention (higher level) | Increased difficulty, system feedback; optional recreational game |
| 8 | Immediate & working memory (higher level) | Increased difficulty; system feedback |
| 9 | Selective attention with distractors | Add auditory & visual distractors; optional recreational game |
| 10 | Sustained attention with distractors | Add distractors to sustained attention games; an optional recreational game |
| 11 | General attention with distractors | Add distractors to general attention games; optional recreational game |
| 12 | Immediate & working memory with distractors | Add distractors to memory games; optional recreational game |

## Results

The present study examined the effects of a digital psychoeducational intervention on semantic and phonemic verbal fluency in students with dyslexia and dysgraphia. Descriptive and inferential statistics were conducted using SPSS 24. Both univariate analysis of covariance (ANCOVA) and multivariate analysis of covariance (MANCOVA) were employed to test the research hypotheses.

### Assumption Testing (Preliminary Checks)

Before performing ANCOVA and MANCOVA, the following assumptions were examined:

**Table 1**
**Shapiro–Wilk Test for Normality of Post-test Scores**

| Variable | Group | Statistic | df | Sig. |
|---|---|---|---|---|
| Semantic VF | Experimental | .97 | 15 | .41 |
| | Control | .96 | 15 | .29 |
| Phonemic VF | Experimental | .97 | 15 | .38 |
| | Control | .96 | 15 | .32 |

All post-test scores were normally distributed (p > .05), satisfying the fundamental parametric assumption of normality required for subsequent analyses.

**Table 2**
**Levine's Test for Homogeneity of Error Variances**

| Variable | F | df1 | df2 | Sig. |
|---|---|---|---|---|
| Semantic VF | .12 | 1 | 28 | .73 |
| Phonemic VF | .46 | 1 | 28 | .50 |

Non-significant results indicate equality of error variances across groups (p > .05), supporting the assumption required for ANCOVA.

**Table 3**
**Test of Homogeneity of Regression Slopes**

| Variable | F | df1 | df2 | Sig. |
|---|---|---|---|---|
| Semantic VF | .51 | 1 | 27 | .48 |
| Phonemic VF | .33 | 1 | 27 | .56 |

Regression slopes were homogeneous across groups, meeting ANCOVA assumptions that covariates relate similarly to post-test scores.

**Table 4**
**Box's M Test for Equality of Covariance Matrices (MANCOVA)**

| Statistic | Value | F | df1 | df2 | Sig. |
|---|---|---|---|---|---|
| Box's M | 4.82 | 1.51 | 2 | 25 | .21 |

Equality of covariance matrices is confirmed (p > .001), supporting the use of MANCOVA for multivariate testing.

**Table 5**
**Means and Standard Deviations of Verbal Fluency Scores**

| Variable | Group | Pre-test M (SD) | Post-test M (SD) |
|---|---|---|---|
| Semantic VF | Experimental | 35.58 (9.39) | 50.25 (9.63) |
| | Control | 35.92 (9.54) | 35.75 (9.55) |
| Phonemic VF | Experimental | 6.58 (4.19) | 8.42 (3.96) |
| | Control | 6.75 (3.91) | 7.08 (3.65) |

**Table 6**
**Results of Multivariate Analysis of Covariance (MANCOVA) for Semantic and Phonemic Verbal Fluency**

| Test | Value | F | Df | Error df | Sig | Effect size |
|---|---|---|---|---|---|---|
| Pillai's Trace | .916 | 148.33 | 2 | 26 | .001 | .920 |
| Wilks' Lambda | .084 | 148.33 | 2 | 26 | .001 | .920 |
| Hotelling's Trace | 10.94 | 148.33 | 2 | 26 | .001 | .920 |
| Roy's Largest Root | 10.94 | 148.33 | 2 | 26 | .001 | .920 |

As observed in Table 8, the results of the multivariate analysis of covariance in the experimental and control groups indicate that these groups differ significantly in at least one of the dependent variables.

**First Hypothesis: Semantic Verbal Fluency**

Hypothesis: Digital psychoeducational interventions improve semantic verbal fluency.

**Table 7**
**Results of Univariate Analysis of Covariance for Semantic Verbal Fluency**

| Source | SS | df | MS | F | Sig. | Effect size |
|---|---|---|---|---|---|---|
| Pre-test | 1661.30 | 1 | 1661.30 | 96.59 | .001 | .821 |
| Group | 1314.88 | 1 | 1314.88 | 76.45 | .001 | .784 |
| Error | 361.20 | 27 | 13.38 | | | |

After controlling for pre-test scores, the intervention significantly increased semantic verbal fluency ($\eta^2 = .784$), confirming the first hypothesis.

**Second Hypothesis: Phonemic Verbal Fluency**

Hypothesis: Digital psychoeducational interventions improve phonemic verbal fluency.

**Table 8**
**Results of Univariate Analysis of Covariance for Phonemic Verbal Fluency**

| Source | SS | df | MS | F | Sig. | Effect size |
|---|---|---|---|---|---|---|
| Pre-test | 293.06 | 1 | 293.06 | 229.82 | .001 | .916 |
| Group | 13.18 | 1 | 13.18 | 10.35 | .004 | .330 |
| Error | 26.78 | 27 | 0.99 | | | |

The intervention significantly improved phonemic verbal fluency ($\eta^2 = .330$), confirming the second hypothesis.

## Discussion

The findings of this study indicate that digital psychoeducational interventions significantly improved the semantic and phonemic verbal fluency of students with dyslexia and dysgraphia. This is consistent with prior research (Akhundi Yamchi et al., 2021; Radfar et al., 2016; Khoddami et al., 2017; Mahrooghi et al., 2020; Boivin et al., 2016; Mayer et al., 2019), as well as recent studies highlighting the potential of digital interventions in enhancing language and executive functioning in students with learning disorders (Kanniainen, 2022; Han &Wang, 2025).

These results reinforce the notion that educational plans for students with learning disorders should explicitly account for their cognitive and linguistic deficits by leveraging their attentional and executive capacities to support more effective learning (Maleki et al., 2024). Students with dyslexia and dysgraphia are known to exhibit inefficiencies in processing speed, phonemic awareness, auditory and visual processing, and verbal reasoning (Krull et al., 2018). Recent evidence confirms that early testing of phonemic processing and naming speed remains a valuable diagnostic tool (Basharpoor et al, 2024). Strengthening these underlying cognitive functions demonstrates a positive impact on reading, writing, and verbal fluency outcomes.

The observed improvements align closely with executive function theory, which posits that verbal fluency depends on key executive processes: working memory, inhibitory control, and cognitive flexibility (Miyake et al., 2000). The intervention's focus on tasks that reinforce attention, working memory, and response inhibition mirrors the components of the central executive system described by Baddeley (2000). The digital games structured, escalating cognitive challenges likely enhanced these executive processes, thereby facilitating better verbal fluency performance.

From the perspective of neuroplasticity, the digital psychoeducational program provides repeated, multisensory stimulation that promotes synaptic changes and neural network reorganization, particularly in brain areas involved in language, attention, and memory (Kolb & Gibb, 2014). This is supported by studies such as Kanniainen (2022) and Zhang et al. (2019), which documented both behavioral and neural improvements following computer-assisted cognitive training in children with learning disabilities.

Furthermore, the findings resonate with Vygotsky's socio-cultural theory, which emphasizes the importance of mediated learning through tools and scaffolding within a learner's zone of proximal development (Vygotsky, 1978). The digital platform functioned as a mediational tool, providing adaptive feedback and engaging students in progressively challenging tasks that scaffolded their cognitive and linguistic skills. This dynamic interaction between learner and tool facilitated cognitive growth beyond the child's initial capacity.

The consistency of our findings with research by Han & Wang (2025), who reported improvements in verbal fluency through gamified working memory training in dyslexic children, strengthens the evidence that digital interventions addressing executive functions are effective. Similarly, Boivin et al. (2016) and Mayer et al. (2019) found that computerized cognitive rehabilitation improved executive functioning components relevant to verbal fluency. However, some studies, such as Naeem & Khan (2024), observed mixed or more modest effects, particularly in phonemic fluency. These differences may be due to variations in intervention duration, task adaptivity, and participant characteristics, including the severity and heterogeneity of learning disorders. The comprehensive, multi-domain design and adequate length of the current intervention likely contributed to the robust improvements observed.

Based on the linguistic approach, learners with dyslexia and dysgraphia encounter problems rooted in phonemic awareness, syllable and letter recognition, phoneme blending, grammar, semantics, and comprehension (Hallahan et al., 2013). A deep understanding of these cognitive gaps equips educational professionals to develop intelligent, multi-sensory digital tools. Such tools are designed to provide targeted stimulation, thereby enhancing learners' visual, auditory, and mnemonic capabilities (Naeem & Khan, 2024). The present findings confirm that computer-based interventions foster these capacities by teaching orientation, response inhibition, sequential command following, and memory strategies. Such activities directly contribute to reinforcing working memory and verbal fluency, which are closely connected components of executive functioning (Han &Wang, 2025).

Neuroimaging studies (Kearns et al., 2019; Zhang et al., 2019) have shown that multiple overlapping brain regions are activated during reading, attention, and memory tasks. Computer-based interventions leverage this potential by systematically integrating visual and auditory stimuli with requirements for rapid motor response. This integrated approach promotes the development of processing speed, reaction time, and intermodal integration; capacities fundamental to the acquisition of robust reading, writing, and verbal fluency skills. As Li et al. (2025) note, integration of sound, image, and motor feedback in digital games strengthens cognitive circuits involved in literacy.

The findings highlight that verbal fluency is not merely a linguistic ability but is intricately linked with executive control and neuroplastic changes in the brain. The implementation of digital psychoeducational tools represents a potentially valuable approach, combining engagement with scalability, to target and reinforce the specific cognitive and linguistic deficits associated with dyslexia and dysgraphia. Computer games integrating concurrent visual, auditory, and motor demands can support the development of essential connections between phonemic awareness, working memory, and processing speed—core cognitive components that underpin proficient reading and writing.

Given that many brain regions are involved in both reading and attention and memory processes (Kearns et al., 2019), computer games lead to further reinforcement of processing speed and accuracy regarding visual and auditory effects, the importance of speed of action and fast reactions in computer games, and involve brain regions related to working memory and reaction time. Furthermore, the foundational process of linking distinct visual and auditory symbols with sequenced finger movements is critical for developing literacy. Consequently, in computer-based interventions, the systematic pairing of sound and image with appropriate haptic feedback is of paramount importance. Therefore, reinforcing the connection between image, sound, and finger movements can improve reading, writing, and verbal fluency.

Therefore, a structured, comprehensive, and intensive treatment approach can be useful. The computer-based educational method, derived from the integration of cognitive neuroscience and information technology, addresses deficits in cognitive functions such as attention and memory. Grounded in the principles of neuroplasticity and the brain's inherent capacity for self-repair, this method employs successive stimulation of underactive neural regions to induce sustained synaptic changes. Consequently, it holds potential for ameliorating cognitive deficits associated with various neurodevelopmental and acquired disorders.

Importantly, our findings confirm that students with comorbid dyslexia and dysgraphia display lower performance in executive functions, including verbal fluency, than their typically developing peers. These deficits can significantly impede their academic and daily functioning. Teaching executive skills such as working memory, cognitive flexibility, and inhibitory control has been shown to improve educational performance and social competence (Maleki et al., 2024). Timely diagnosis and intervention remain essential to mitigate these challenges.

Considering that extensive brain regions are involved in both the reading process and attention and memory (Kearns et al., 2019), regarding the greater effectiveness of computer methods, it can be said that computer games, in terms of visual and audio features, and the importance of speed of action and quick reactions in computer games, and the involvement of brain regions related to active memory and reaction time, lead to further strengthening of processing speed and accuracy. On the other hand, considering that establishing a connection between different visual signs and their connection with sound signs along with chain movements of fingers plays an important role in the formation of reading and writing skills (Brooks et al., 2011), it can be said that connecting sound and image along with appropriate motor feedback by fingers is crucial in computer games, so strengthening the skill of connecting image and sound and finger movements can lead to improving reading, writing and verbal fluency skills. Therefore, using a structured, comprehensive, and intensive therapeutic approach can be useful. The computer training method, integrating cognitive neuroscience with information technology, is a method to improve cognitive function deficiencies, including attention and memory. Based on the principle of self-healing and brain plasticity, this method creates lasting synaptic changes in the brain by successively stimulating fewer active areas, thereby improving the cognitive deficits observed in the aforementioned disorders (O'Connell et al., 2007).

Based on the present study, children with comorbidity of dyslexia and dysgraphia have a lower performance in executive functions (verbal fluency) than normal children; defects in these functions can cause serious problems for students in completing school assignments and personal affairs. Since teaching the skills of executive actions positively affects the improvement of academic performance of these children, timely diagnosis and intervention are essential. Like other studies, the present research had limitations despite its findings and achievements. More accurate and reliable results can be achieved by considering these limitations and solving them in future studies. The generalizability of the results is limited by methodological constraints, notably the study's reliance on a convenience sample and its relatively small sample size. Due to the limited research time, it was impossible to implement the follow-up phase, thereby affecting the continuous effectiveness of the intervention program. Furthermore, the severity of dyslexia and dysgraphia was not controlled. Therefore, other researchers interested in this field are suggested to increase the sample size, use random sampling to obtain a representative sample of the population, control the severity of the disorder, and also evaluate it in the follow-up phase to investigate the long-term effect of cognitive rehabilitation using computers.

**Authors' contributions**

All authors contributed equally to the preparation of this article.

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**Ethics declaration**

All ethical principles were considered in this research. This research was derived from an educational training project conducted as part of an MSc dissertation in Educational Psychology at Shahid Rajaee Teacher Training University.

**Declaration of interest**

The authors declared no conflict of interest.

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