EXPERIENCE REPORT

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Neuropsychological rehabilitation for executive functions in a patient with dyslexia: A single-case experimental design study

Reabilitação neuropsicológica para funções executivas em um paciente com dislexia: Estudo com delineamento experimental de caso único

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Summary

Objective: Dyslexia is a developmental disorder that impairs different cognitive functions and requires interdisciplinary treatment. Until now, the literature describing neuropsychological rehabilitation programs for young people with dyslexia is scarce. This single-case experimental study aimed to investigate the effects of a neuropsychological rehabilitation program for executive functions in a patient with developmental dyslexia. **Methods:** The patient was a 13-year-old boy attending the 7th grade of elementary school who was assessed by executive functions and reading comprehension instruments. The intervention consisted of 28 sessions of 60 minutes per week and the patient was reassessed post-intervention by the same instruments. Patient's scores were compared to a control sample of six students without learning disabilities. All statistical analyses were performed using a program specifically developed for single-case experimental design studies in neuropsychology. **Results:** The intervention positively affected inhibitory control, working memory, planning, use of learning and comprehension strategies, and reading comprehension. **Considerations:** This study shows the efficacy of a neuropsychological rehabilitation program and indicates that this type of intervention can help reduce executive functions deficits in patient with developmental dyslexia.

Keywords: Neuropsychology. Rehabilitation. Executive Function. Dyslexia, Adolescent.

Resumo

Objetivo: A dislexia é um transtorno do desenvolvimento que prejudica diferentes funções cognitivas e requer tratamento interdisciplinar. Até o momento, a literatura descrevendo programas de reabilitação neuropsicológica para jovens com dislexia é escassa. Este estudo experimental de caso único teve como objetivo investigar os efeitos de um programa de reabilitação neuropsicológica para funções executivas em um paciente com dislexia do desenvolvimento. **Método:** O paciente era um menino de 13 anos frequentando o 7º ano do Ensino Fundamental, que foi avaliado por instrumentos de funções executivas e compreensão de leitura. A intervenção consistiu em 28 sessões de 60 minutos por semana, e o paciente foi reavaliado pós-intervenção pelos mesmos instrumentos. As pontuações do paciente foram comparadas a uma amostra de controle de seis estudantes sem deficiências de aprendizado. Todas as análises estatísticas foram realizadas usando um programa desenvolvido especificamente para estudos de *design* experimental de caso único em neuropsicologia. **Resultados:** A intervenção afetou positivamente o controle inibitório, a memória de trabalho, o planejamento, o uso de estratégias de aprendizado e compreensão, e a compreensão de leitura. **Considerações:** Este estudo mostra a eficácia de um programa de reabilitação neuropsicológica e indica que este tipo de intervenção pode ajudar a reduzir os déficits de funções executivas em pacientes com dislexia do desenvolvimento.

Unitermos: Neuropsicologia. Reabilitação. Função Executiva. Dislexia. Adolescente.

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Introduction

Developmental dyslexia (DD) is a neurobiological disorder characterized by significant deficits in the acquisition and development of reading and writing skills whose diagnosis should be done by an interdisciplinary team based on the patient's clinical profile and according to international guidelines (American Psychiatric Association [APA], 2023; World Health Organization [WHO], 2022).

The neuropsychological profile of individuals with DD shows difficulties in different cognitive domains relative to that of proficient readers (Cruz-Rodrigues et al., 2014; Lima et al., 2013; Mingozzi et al., 2024; Zoubrinetzky et al., 2014). In addition to cognitive deficits in phonological processing5, (de Groot et al., 2015; Navas et al., 2014) children with DD also have difficulties in executive function (EF) domains, including inhibitory control, mental flexibility, working memory, strategy use, and verbal fluency (Barbosa et al., 2019; Lima, et al., 2013; Moura et al., 2014; Zoubrinetzky et al., 2014).

EFs are a family of cognitive abilities that help the individual to make decisions autonomously (Diamond, 2013, 2020) and thus are linked to the development of self-regulated behaviors (Bjork et al., 2013). From a functional standpoint, academic areas that depend on EF processes, including written production and reading comprehension, homework, long-term projects, and taking tests and notes, can be adversely affected by executive deficits (Meltzer, 2010; Nouwens et al., 2021; Ruffini et al., 2024; Spiegel et al., 2021).

The main treatment for dyslexia is based on the phonological approach, combining phonological awareness training and reading fluency training (Darrot et al., 2023; Galuschka et al., 2014; Harrar-Eskinazi et al., 2022; Martins et al., 2020). Nevertheless, neuropsychological intervention has also shown positive results to minimize cognitive and behavioral deficits in individuals with acquired brain injuries (Starrfelt et al., 2013; Gazzellini et al., 2012) or dysfunctions, as in the case of DD (Lorusso et al., 2011; Nukari et al., 2020; Robertson, 2000).

Neuropsychological rehabilitation (NR) aims to reduce the impact caused by cognitive deficits, increasing the individual's repertoire of strategies. NR can also assist in psychological adaptation by expanding coping strategies, and enhancing self- understanding and acceptance (Nukari et al., 2020; Wilson, 2009). Previous studies on neuropsychological interventions with young dyslexics has shown effective for improved performance in reading accuracy and comprehension through stimulation of sensory processing, visual attention, and executive functions (Goldstein & Obrzut, 2001; Lorusso et al., 2011; Taran et al., 2023).

Single-case experimental design (SCED) studies have been used to investigate the validity of intervention programs in neuropsychology (Evans et al., 2014; Krasny-Pacini, 2023). Statistical methods for estimating parameters and assessing the quality and internal validity of SCED studies have been specifically developed for such studies (McIntosh & Rittmo, 2021). For instance, a meta-analysis of single-subject- design intervention studies for students with learning disabilities showed that direction instruction models and cognitive strategies yielded more robust effect sizes on academic skills such as reading (Swanson & Sachse-Lee, 2000). Another study indicates that the association between cognitive training of executive functions (EF) and phonological-based treatment was more effective in enhancing reading skills in groups with dyslexia. This suggests that gains in reading may be linked to improvements in executive functions (Pasqualotto & Venuti, 2020).

Despite the positive results, few studies have addressed more complex reading processes, including comprehension and its underlying cognitive mechanisms such as EFs, using a neuropsychological approach. Thus, this single-case experimental study aimed to investigate the applicability of adopting a neuropsychological rehabilitation program for executive functions in a patient with developmental dyslexia.

Methods

Participant

This is a single-case experimental design study, which uses repeated measures to evaluate the

efficacy of a particular intervention (Crawford et al., 2010; Evans et al., 2014; Krasny-Pacini, 2023; Loschiavo-Alvares et al., 2013; Manolov et al., 2014). Given the method's requirements, the case's scores were compared to a control sample (Crawford et al., 2010; McIntosh & Rittmo, 2021; Swanson & Sachse-Lee, 2000).

The study was approved by the Research Ethics Committee at the School of Medical Sciences, State University of Campinas, under protocol n. 543.108/2014. The families signed an Informed Consent Form.

The patient was a right-handed, native Portuguese speaker, 13-year-old boy of middle socioeconomic status, attending the 7th grade of middle school at a public school. The patient had no history of neurological disorders or psychiatric problems, no alterations in sensory tests (visual acuity and audiometry), and was not receiving medical treatment or attending other intervention programs for learning disabilities.

The diagnosis was made by a multidisciplinary team (neuropsychology, speech-language pathology, and educational psychology) in a research center for learning disorders and was based on the criteria of the International Classification of Diseases (ICD-11) (WHO, 2022), Diagnostic and Statistical Manual of Mental Disorders (DSM-5-TR) (APA, 2023) and clinical characteristics: average Full Scale IQ (94) on the Wechsler Intelligence Scale for Children, Fourth Edition (WISC-IV) (Rueda et al., 2013); significant impairment in reading skills and phonological processing on language assessment; and no significant behavioral or emotional complaints by parent report on the Child Behavior Checklist (CBCL) (Achenbach & Rescorla, 2001) (z=0.04; total score). The participant needed to have achieved at least the alphabetic level of reading proficiency to be included in the study.

The control sample consisted of six participants (three boys) of upper and upper- middle socioeconomic status aged 13–16 years and attending between the 8th grade of middle school and the 2nd year of high school in private and public schools. These participants had achieved the orthographic level of reading proficiency and reported no history of behavioral complaints or learning disabilities.

Instruments

Executive Functions

1. Stroop Color-Word Test (SCWT) (Fonseca et al., 2015): assesses inhibitory control. Time and error scores were recorded for the color-word card (incongruent).
2. Trail Making Test (TMT-B) (Fonseca et al., 2015): assesses mental flexibility. Time and total error (switching errors and sequencing errors) scores were recorded.
3. Wisconsin Card Sorting Test (WCST) (Cunha et al., 2005): assesses the ability to shift cognitive strategies in response to changing contingencies. The following scores were recorded: number of categories completed, number correct, % errors, and perseverative responses.
4. Backward Corsi Block-Tapping Task (Kessels et al., 2000): assesses visuo-spatial sketchpad. Total scores (span x number correct) were recorded.
5. Backward Digit and Letter-Number Sequencing (Rueda et al., 2013): WISC-IV subtests that assess phonological loop in working memory. The age--weighted scores were recorded.
6. Working Memory Index (WMI) (Rueda et al., 2013): a WISC-IV index expressed by an age--specific score.
7. Tower of London (ToL) (Fonseca et al., 2015): assesses planning and problem-solving skills. The total number of correctly solved problems was recorded.
8. Iowa Gambling Test (IGT) (Malloy-Diniz et al., 2008): assesses decision-making capacity. Net scores were calculated from a formula that represents the tendency to choose from different decks: (C+D) - (A+B).
9. Verbal Fluency Test (FAS) (Fonseca et al., 2015): assesses the ability to say words using phonological or semantic clues. The average scores for each category were recorded.
10. Learning Strategies Assessment Scale (EAVAP) (Boruchovitch & Santos, 2010): assesses the use of strategies in learning situations. Percent

cognitive, metacognitive, and total scores were recorded.

11. Metacognitive Awareness of Reading Strategies Inventory (MARSI) (Guan et al., 2011): assesses different strategies used in reading. Overall average scores were recorded. The scoring scale ranges from low (≤ 2.4) to medium (2.5–3.4) and high (≥ 3.5).
12. Executive Functioning Semi Structured Interview (EFSI) (Kaufman, 2010): parent, student, and teacher versions assess different EF domains in the school and family settings. Percent totals were considered; high values represent a higher frequency of complaints.

Reading parameters

1. Reading and comprehension (Corso et al., 2015): the patient was given a 210-word narrative text with a 61-part propositional structure. The following parameters were evaluated: reading level (logographic, alphabetic, or orthographic), decoding strategy (phonological or lexical), fluency (number of words read in 60 s/total reading time in s), and comprehension (oral retelling: % propositions retold; 10-question questionnaire: % correct answers).
2. Cloze Test (Oliveira et al., 2012): narrative text with 40 words deleted to assess reading comprehension. The score was calculated from the formula: Σ correctly guessed words x 100/ number of words deleted. Reading performance was rated as poor (<44%), average (44–57%), or above average (proficient reader) (>57%).

Procedure

Assessments were conducted by psychologist, neuropsychologist, and speech therapy pathologist at the following stages:

1. Pre-intervention: patient, parents, and teachers were evaluated based on EF and reading instrument scores (response variables);
2. Intervention: the patient attended a neuropsychological rehabilitation program for executive functions (Lima et al., 2017), consisting of a total of 28 weekly sessions of 60 minutes each. The intervention aimed to stimulate EF skills and promote self-regulated learning, especially study and reading comprehension competencies. The patient was instructed and monitored to learn EF strategies that could be used in the school and family settings. Treatment was divided into four modules: (i) Psychoeducation with patient, parents, and teachers about DD, EF, and the intervention program; (ii) Advice to parents and teachers for structuring a tutoring system, guiding changes in space, and monitoring the use of strategies; (iii) Executive functions applied to study skills: developing strategies that help in managing time, organizing materials and space, homework, studying for tests, and taking notes; (iv) Executive functions applied to reading comprehension: developing strategies that help in reading comprehension by using metacognitive resources;
3. Post-intervention: patient, parent, and teacher assessment using pre-intervention instruments.

Statistical analyses

All statistical analyses were performed using the Singlims_ES.exe program developed by Crawford et al. (2010) for use in single-case studies employing the case-controls design in neuropsychology. The program uses a modified t test to compare pre-intervention and post-intervention scores between case and controls. The significance level (*p* value), effect size (zcc), and confidence interval (CI) are calculated based on score changes. The *p* value is a measure of the generalization of the results. Differences were considered significant at $p \leq 0.05$. The effect size z is an analogue of Cohen's d and compares a single-case's score to a control sample with a 95% confidence interval. The effect size was considered low (=.20), medium (=.50), or high (=.80). Lastly, the CI captures the uncertainty over the true effect size, i.e., the percentage of the control population obtaining a lower score than the case (Crawford et al., 2010; Manolov et al., 2014).

Results

Tables 1 and 2 show pre- and post-intervention comparisons for the different EF instruments between the patient and controls. Significant differences between patient and controls were observed in pre-treatment SCWT (time), TMT-B (time), Letter--Number Sequencing, WMI, ToL, WCST (perseverative), EAVAP (cognitive, metacognitive, and total), EFSI (patient, parents, and teacher), cloze test, reading speed, and question answering (Table 1). Marginally significant differences in Backward Digit, FAS (phonology), and MARSI (total) were observed between case and controls. Pre-intervention reading by the patient was predominantly phonological and at the alphabetic level, MARSI score was low, and cloze was poor.

Table 1

Pre-intervention comparison between the patient and controls

Scores	Control group (n=6) mean ± SD	Patient's score	Significance test		Effect size estimate (z_{cc})		Estimated percentage of the control group obtaining a lower score than the patient	
Pre-intervention			***t***	***p***	**Point**	**(95% CI)**	**Point**	**(95% CI)**
Age	14.17±1.47	13	-0.74	0.25	-0.8	-1.70–0.17	24.72	4.45–56.54
SCWT (time)	24.17±8.04	49	2.86	0.02	3.09	1.06–5.09	98.23	85.59–99.99
SCWT (errors)	0.5±1.22	1	0.38	0.36	0.41	-0.45–.23	64.0	32.79–89.05
TMT-B (time)	92.0±36.61	253	4.07	<0.001	4.4	1.65–7.15	99.52	95.06–100.0
Backward Corsi	55.5±15.81	48	-0.44	0.34	-0.47	-1.3–0.4	33.94	9.61–65.38
Backward Digit	9.33±1.63	6	-1.89	0.06	-2.04	-3.48–0.56	5.86	0.02–28.92
Letter-Number Sequencing	10.67±0.52	9	-2.97	0.02	-3.21	-5.28– -1.12	1.55	0.0–13.16
WMI	100.0±5.37	85	-2.59	0.02	-279	-4.63– -0.92	2.45	0.0–17.78
ToL	22.0±1.9	17	-2.44	0.03	-2.63	-4.38– -0.85	2.95	0.0–19.86
WCST (correct)	71.17±9.26	71	-0.02	0.49	-0.02	-0.82–0.78	49.35	20.68–78.31
WCST (errors)	82.5±20.98	96	0.6	0.29	0.64	-0.27–1.51	71.14	39.34–93.42
WCST (perseverative)	50.33±3.14	34	-4.82	<0.001	-5.2	-8.42– -1.99	0.24	0.0–2.28
IGT (net score)	2.0±22.09	-4	-0.25	0.41	-0.27	-1.077–0.56	40.57	14.1–71.15
FAS (phonology)	10.61±1.76	7.0	-1.9	0.06	-2.05	-3.50– -0.56	5.8	0.02–28.78
FAS (semantic)	14.89±1.56	12.33	-1.52	0.09	-1.64	-2.88– -0.34	9.46	0.2–36.56
EAVAP (cognitive)	60.83±18.35	5	-2.82	0.02	-3.04	-5.02– -1.04	1.86	0.0–14.9
EAVAP (metacognitive)	81.67±9.83	55	-2.51	0.03	-2.71	-4.51– -0.89	2.69	0.0–18.79
EAVAP (total)	87.5±14.05	25	-4.12	<0.001	-4.45	-7.29– -1.67	0.5	0.0–4.72
MARSI (total)	3.65±0.7	2.27	-1.83	0.06	-1.97	-3.38– -0.52	6.38	0.04–30.19
EFSI (Patient)	16.19±7.44	35	2.34	0.03	2.53	0.8–4.22	96.68	78.73–100.0
EFSI (Parents)	17.25±10.39	57	3.54	0.01	3.83	1.4–6.25	99.17	91.88–100.0
EFSI (Teacher)	1.19±1.4	39	25.0	<0.001	27.01	10.99–43.28	99.99	100.0
Reading speed	177.6±11.33	29.43	-12.11	<0.001	-13.08	-20.99–5.28	0.0	0.0
Oral retelling	24.19±7.59	18.03	-0.75	0.24	-0.812	-1.72–0.15	24.31	4.26–56.12
Question answering	78.0±10.95	50	-2.37	0.03	-2.56	-4.27– -0.81	3.21	0.0–20.87
Cloze	83.0±11.91	20	-4.9	<0.001	-5.29	-8.56– -2.04	0.22	0.0–2.08

Note: SCWT - Stroop Color Word Test, TMT - Trail Making Test, WMI - Working Memory Index, WCST - Wisconsin Card Sorting Test, IGT - Iowa Gambling Task, FAS - Fluency Verbal Test, EAVAP - Learning Strategies Assessment Scale, MARSI - Metacognitive Awareness of Reading Strategies Inventory, EPSI - Executive Functioning Semi Structured Interview..

Table 2

Post-intervention comparison between the patient and controls

Scores	Control group (n=6) mean ± SD	Patient's score	Significance test		Effect size estimate (zcc)		Estimated percentage of the control group obtaining a lower score than the patient	
Post-intervention			**t**	**p**	**Point**	**(95% CI)**	**Point**	**(95% CI)**
SCWT (time)	24.17±8.04	34	1.13	0.16	1.22	0.11–2.28	84.55	54.21–98.87
SCWT (errors)	0.5±1.22	2	1.14	0.15	1.23	0.11–2.29	84.67	54.37–98.9
TMT-B (time)	92.0±36.61	108	0.41	0.35	0.44	-0.42–1.26	64.88	33.57–89.63
Backward Corsi	55.5±15.81	54	-0.09	0.47	-0.1	-0.89–0.71	46.67	18.61–76.17
Backward Digit	9.33±1.63	8	-0.76	0.24	-0.82	-1.73–0.15	24.2	4.21–56.01
Letter-Number Sequencing	10.67±0.52	9	-2.97	0.02	-3.21	-5.28– -1.12	1.55	0.0–13.16
WMI	100.0±5.37	91	-1.55	0.09	-1.68	-2.94– -0.36	9.07	0.17–35.84
ToL	22.0±1.9	20	-0.98	0.19	-1.05	-2.04– -0.0	18.73	2.05–49.92
WCST (correct)	71.17±9.26	71	-0.02	0.49	-0.02	-0.82–0.78	49.35	20.68–78.31
WCST (errors)	82.5±20.98	96	0.51	0.32	0.55	-0.34–1.39	68.33	36.69–91.8
WCST (perseverative)	50.33±3.14	21	-8.65	<0.001	-9.34	-15.01– -3.74	0.02	0.0–0.01
IGT (net score)	2.0±22.09	26	1.01	0.18	1.09	0.02–2.09	81.97	50.92–98.17
FAS (phonology)	10.61±1.76	6.0	-2.43	0.03	-2.62	-4.37– -0.84	2.99	0.0–20.02
FAS (semantic)	14.89±1.56	14.33	-0.33	0.38	-0.36	-1.17–0.49	37.66	12.06–68.65
EAVAP (cognitive)	60.83±18.35	70	0.46	0.33	0.50	-0.38–1.33	66.85	35.34–90.88
EAVAP (metacognitive)	81.67±9.83	80	-0.16	0.44	-0.17	-0.97–0.65	44.06	16.64–74.05
EAVAP (total)	87.5±14.05	80	-0.49	0.32	-0.53	-1.37–0.35	32.11	8.47–63.71
MARSI (total)	3.65±0.7	3.63	-0.03	0.49	-0.03	-0.83–0.77	49.0	20.4–78.03
EFSI (Patient)	16.19±7.44	33	2.09	0.05	2.26	0.67–3.81	95.47	74.69–99.99
EFSI (Parents)	17.25±10.39	49	2.83	0.02	3.06	1.05–5.04	98.16	85.24–99.99
EFSI (Teacher)	1.19±1.4	41	26.33	<0.001	28.44	11.57–45.57	99.99	100
Reading speed	177.6±11.33	43.45	-10.96	<0.001	-11.84	-19.01–4.77	0.0	0.0
Oral retelling	24.19±7.59	27.87	0.45	0.34	0.49	-0.39–1.32	66.38	34.92–90.59
Question answering	78.0±10.95	80	0.17	0.44	0.18	-0.63–0.98	56.38	26.31–83.69
Cloze	83.0±11.91	47.5	-2.76	0.02	-2.98	-4.93– -1.01	1.99	0.0–15.58

Note: SCWT - Stroop Color Word Test, TMT - Trail Making Test, WMI - Working Memory Index, WCST - Wisconsin Card Sorting Test, IGT - Iowa Gambling Task, FAS - Fluency Verbal Test, EAVAP - Learning Strategies Assessment Scale, MARSI - Metacognitive Awareness of Reading Strategies Inventory, EPSI - Executive Functioning Semi Structured Interview.

Significant differences persisted between case and controls in post-intervention Letter--Number Sequencing, WCST (perseverative), FAS (phonology), EFSI, reading speed, and cloze test (Table 2).

Reading by the patient was predominantly lexical and at the orthographic level, MARSI score was medium, and cloze was average. No comparisons were made for TMT-B and WCST (categories) because both case and controls made no errors in

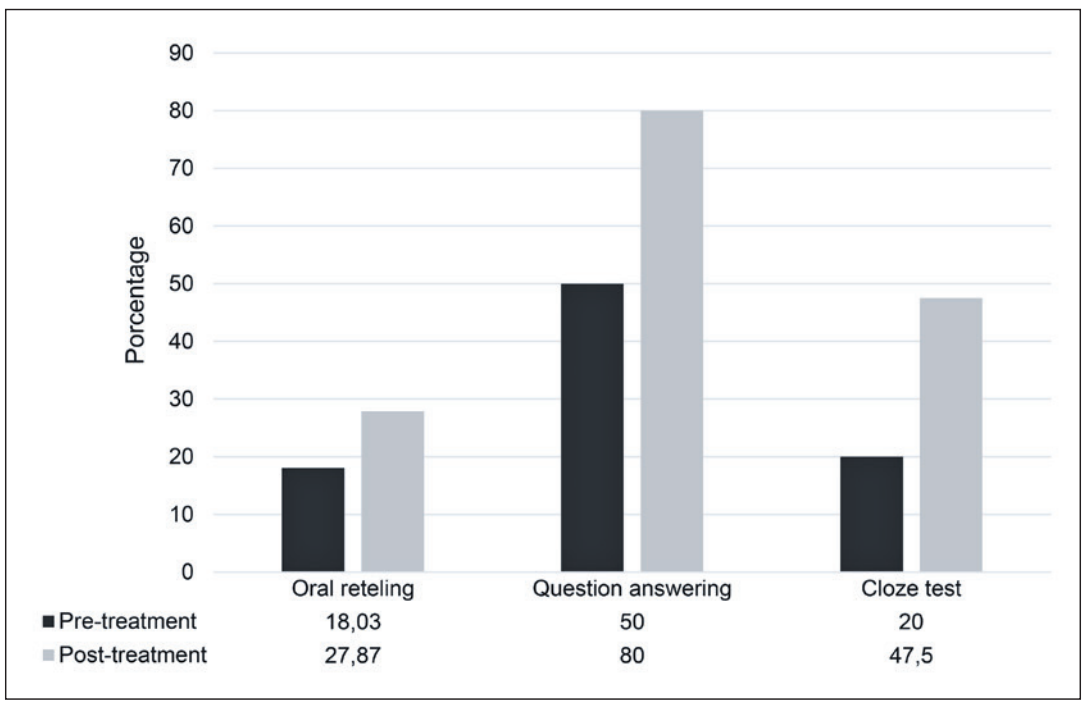
the TMT-B and completed the six WSCT categories in pre- and post-intervention tests. Figure 1 shows the pre- and post-intervention case's scores for oral retelling, question answering, and cloze test.

Discussion

The patient obtained lower pre-intervention scores than controls on neuropsychological (inhibitory control, cognitive flexibility, phonological loop in working memory, phonological verbal fluency, and planning), and ecological (cognitive and metacognitive learning strategies, reading comprehension strategies, EFs applied to the school and family settings) measures of EFs and reading parameters (reading speed and comprehension). EF deficits (Barbosa et al., 2019; Cruz-Rodrigues et al., 2014; Lima et al., 2013; Moura et al., 2014; Zoubrinetzky et al., 2014) may be an integral part of the neuropsychological profile of DD and should be considered for diagnosis and intervention.

From a clinical standpoint, the NR program was effective for improving inhibitory control, cognitive flexibility, working memory, planning, use of learning and comprehension strategies, and reading comprehension. Post-intervention reading speed remained slow, but both predominant decoding strategy and reading level improved, from phonological to lexical and alphabetic to orthographic, respectively. It should be noted that the intervention did not include training for decoding skills such as phonological awareness (Darrot et al., 2023; Galuschka et al., 2014; Martins et al., 2020) or reading parameters such as fluency (Galuschka et al., 2014; Tressoldi et al., 2008). On the contrary, the intervention emphasized metacognitive reading strategies, i.e., increasing the use of comprehension strategies, represented by self-monitoring and self-evaluation activities. Thus, to be included in the study, the patient needed to have achieved at least the alphabetic reading level. Consequently, cognitive resources would be less implicated in decoding

Figure 1
Pre- and post-intervention case's scores for oral retelling, question answering, and cloze



(recognition, grapheme-phoneme conversion) and more available to higher-order reading processes (i.e., reading comprehension).

The number of propositions (macro and microprocesses) recalled by patient on oral retelling was higher at post- than at pre-intervention, even though it was not significantly different from that of controls at baseline. Moreover, the post-intervention number of correct answers in question answering improved significantly. Conversely, reading performance on the cloze test remained significantly poorer than that of controls, even though percent correct answers was higher and overall cloze improved from poor to average. MARSI and EAVAPI results also showed that the patient started to use more comprehension strategies. Similarly, a study that investigated the effect of an intervention program on metacognitive reading processes in 5th and 6th grade students also reported positive results (Gayo et al., 2014). Nevertheless, the current study describes the effects of a clinical and systematic NR program.

Some neuropsychological measures were not affected by NR. The Letter-Number Sequencing score remained unchanged (9) and was lower than that of controls, but fell within the average range for this subtest. Percent perseverative responses on WCST and mean number of words generated on FAS (phonology) were lower at post-intervention. It is possible that these difficulties persisted because of characteristics of the patient's clinical profile. For instance, only the semantic, but not the phonological category was impaired on FAS at pre- and post-intervention, suggesting that the patient had more difficulties in accessing the lexicon through phonological clues (Lima et al., 2013; Navas et al., 2014).

The post-intervention changes promoted by the ecological measures of EFs administered to patient, parents, and teacher did not alleviate the differences between case and controls. These results are inconsistent with clinical observation and with the positive effects observed on other levels of reading and comprehension strategies. In the case of instruments administered to parents and teacher, the results may suggest increased pressure for improved performance in different school tasks. Thus, these findings cannot be interpreted solely as a lack of effect of the intervention on the school and family settings. These ecological measures have been used to determine the efficacy of clinical interventions because they resemble the patient's daily demands (Loschiavo-Alvares et al., 2013). Future studies using standardized instruments that are capable of ranking performance may minimize this limitation.

Some characteristics of the NR program may explain the improvements achieved by the patient. First, the intervention aimed at stimulating EFs by promoting self-regulation in school situations and reading comprehension through explicit instruction and systematic learning of EF strategies so that the patient could deal with school demands. These principles have also been addressed in other interventions involving EF strategies, but from an educational point of view (Gayo et al., 2014).

Secondly, we found that an emphasis on reading comprehension and its strategic aspects has proven effective for children with DD who have fewer decoding deficits. Thus, NR can complement other conventional therapeutic approaches for DD (Darrot et al., 2023; Galuschka et al., 2014; Pasqualotto & Venuti, 2020) and the emphasis on EFs broadens the scope of treatment, which has been previously confined to sensory processing and attention (Lorusso et al., 2011). Another NR approach for dyslexia showed positive effects for decoding, but not for reading comprehension (Lorusso et al., 2011).

Thirdly, parental and school involvement in the psychoeducation and guidance intervention modules may have aided in the transfer of strategies learned to other contexts. The principle of transfer of effects is crucial to the efficacy of any intervention and has been recognized as one of the main challenges for NR (Barnett & Ceci, 2002). Thus, parents and teachers acted as mediators of treatment response, overseeing the training, monitoring, and reinforcement of strategies.

SCED studies have wide applicability in the clinical setting and, in this study, this design enabled the observation of the patient's idiosyncrasies. Nevertheless, using appropriate statistical techniques for the comparison of an individual to a well-matched control sample is central to the success of such studies. Thus, the design (Crawford et al., 2010) used in this study was appropriate to test the effectiveness of NR. Nevertheless, some limitations of this study and perspectives for future studies include: use of standardized ecological measures of EFs; matching case and controls by reading level; a future study with an experimental design for the analysis of the effects of EFs on reading comprehension; inclusion of performance measures in other cognitive domains to evaluate the possible transfer of effects to untrained skills; and follow-up measures to determine the long-term persistence of effects.

Considerations

In conclusion, this study demonstrated the efficacy of a neuropsychological rehabilitation program for developmental dyslexia in a single-case experimental design. Neuropsychological rehabilitation emphasized executive functions and was effective in improving cognitive performance measures, ecological measures of executive functions, and reading parameters. Thus, neuropsychological rehabilitation can be part of the intervention process of individuals with dyslexia, helping minimize deficits and develop compensatory strategies for dealing with difficulties in the school and family settings.

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