Attentional Performance and Executive Functions in Children with Learning Difficulties

Desempenho Atencional e Funções Executivas em Crianças com Dificuldades de Aprendizagem

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Abstract

Studies have described changes in visual attention and executive function in children with developmental dyslexia. This study intended to compare the performance of children with and without learning difficulties on tasks of visual attention and executive functions. The participants were 23 students, aged between 9 and 14 years old, with a mean age of 10.8 years. They were divided into three groups: (a) with learning difficulties; (b) with dyslexia; and (c) control (without any difficulty). For the evaluation, Tests of Cancellation, Trail Making Test, Stroop Color-Word Test and Tower of London Test were used. The results indicated that children with dyslexia had the worst performance on different measures of attention and executive functions, indicating that such changes may be characteristic of the disorder and keep the deficit in the phonological component of language.

Keywords: Visual Attention; Executive Functions; Dyslexia; Neuropsychology.

Resumo

Estudos têm descrito alterações na atenção visual e nas funções executivas em crianças com Dislexia do Desenvolvimento. O presente trabalho pretendeu comparar o desempenho de crianças com e sem dificuldades de aprendizagem em tarefas de atenção visual e funções executivas. Participaram 23 estudantes, com idade entre 9 e 14 anos e idade média de 10,8 anos, divididos em três grupos: com dificuldades escolares, com dislexia e controle sem dificuldades. Para a avaliação foram usados os Testes de Cancelamento, Trail Making Test, Stroop Color Word Test e Tower of London. Os resultados indicaram que as crianças com dislexia apresentaram piores desempenhos em diferentes medidas atencionais e das funções executivas, indicando que tais alterações podem ser características do quadro e acompanhar o déficit no componente fonológico da linguagem.

Palavras-chave: Atenção Visual; Funções Executivas; Dislexia; Neuropsicologia.

Learning disabilities refer to heterogeneous frames that can be divided into two groups: (a) learning difficulties, which can be caused by literacy gaps, inadequacy of teaching methods, excessive school changes, or school problems in the dynamics resulting from various neurological problems, deficiencies or psychosocial factors; (b) learning disabilities, which are the result of dysfunction in the central nervous system (CNS), i.e., failure in processing information regarding reading, writing and arithmetic skills (Lima, Salgado, & Ciasca, 2009).

According to the definition of the National Joint Committee on Learning Disabilities, learning disorders are characterized by difficulties in the acquisition, development and use of written language, speaking, reading, reasoning or mathematical skills, occurring due to CNS dysfunction (Hammill, Leiche, McNutt, & Larsey, 1988; Kavale & Forness, 2000).

One of the specific learning disabilities consists in developmental dyslexia, which has neurobiological origin and is characterized by specific difficulties in written language, resulting from a deficit in the phonological component of language. These difficulties are unexpected in relation to other cognitive abilities, level of intelligence and effective classroom instruction (Lyon, S. E. Shaywitz, & Shaywitz, 2003; B. A. Shaywitz et al., 2001; S. E. Shaywitz & Shaywitz, 2005).

The diagnosis of learning disabilities should be conducted by a multidisciplinary team, so that different aspects are investigated (personal, social, family, school) and cortical functions involved with the child's learning (Lima, Salgado, & Ciasca, 2008; Pestun et al., 2002; Silver et al., 2008).

In this diagnostic process, the neuropsychological evaluation plays a critical role in the investigation of cortical

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functions, characterizing the neuropsychological profile, planning and monitoring the intervention (Castaño, 2002; Silver et al., 2008). According to Castaño (2002), the main objective is to analyze the information processing from the time of entry by the sensory pathways (sensory input) to the organization of the response (motor output).

It is known that, among other functions, attention and executive functions are present at all times of information processing and, consequently, changes can affect the child's learning (Lima, Tabaquim, & Ciasca, 2009).

Attention refers basically to the ability to select between relevant and irrelevant stimuli in order to ensure an effective interaction with the environment and can be divided into selective, sustained, alternating and divided (Lima, 2006; Raz & Buhle, 2006). Different authors often define executive functions as a group of mental abilities that assist the individual in carrying out tasks independently, in an organized, creative, effective and socially adapted way (Denckla, 2007; Gazzaniga, Ivry, & Mangun, 1998; Lezak, 1995; Royall et al., 2008). These are multifaceted and have interdependent construction components such as capacity planning, the use of strategies, mental flexibility and inhibitory control (Anderson, 2002; Tirapu-Ustárroz, Garcia-Molina, Luna-Lario, Roig-Rovira, & Pelegrin-Valero, 2008).

Different studies have shown that changes in attention and executive functions are characteristic of learning disabilities. Regarding attention, studies indicate that dyslexic children compared with children fluent in reading show diffuse distribution of visual processing resources (Facoetti, Paganoni, & Lorusso, 2000), and difficulties in the distribution of visual-spatial attention (Facoetti & Molteni, 2001; Facoetti, Turatto, Lorusso, & Mascetti, 2001), as evidenced by the pattern of slow responses on attention tests (Heiervang & Hugdahl, 2003; Lima et al., 2008; Lima, Salgado, & Ciasca, in press; Lima, Travaini, & Ciasca, 2009a). According to Facoetti and Molteni (2001), such changes may possibly be related to dysfunction in the right parietal cortex.

Similarly, studies that compare the performance of dyslexic children without difficulties in tasks that assess components of executive functions have also described changes. In the work of Reiter, Tucha and Lange (2005), it was observed significant loss in verbal working memory, inhibitory control, verbal fluency and mental flexibility.

Everatt, Warner, Miles and Thomson (1997) investigated the effect of interference on selective attention using the stroop color word test (SCWT), also considered a measure of inhibitory control. It was also compared groups of children with dyslexia, with and without difficulties, but on the same reading level that dyslexic children. The authors found that dyslexic children showed loss in test performance and the results were similar to that of younger children and on the same reading level. Similarly to a study conducted by Lima et al. (2008), 83.3% of dyslexic children assessed showed altered pattern of inhibitory control assessed by SCWT.

According to Brosnan, Hamill, Robson, Shepherd and Cody (2002), individuals with dyslexia show changes in executive functions related to the inhibition of distracting stimuli and the sequencing of events, tasks performed by the left prefrontal cortex.

Despite this evidence, few studies conducted in our context have focused on the characterization of these functions in children with learning difficulties. Therefore, the aim of this research was to compare the performance of children with specific reading/writing with children who experience learning difficulties and without difficulty on measures of visual attention and executive functions.

Method

Participants

This study comprised 23 public school students, i.e., 17 boys (73.9%) and 6 girls (26.1%) aged 9-14 years (mean: 10 years and 8 months), attending middle school 3rd-7th grades (current 4th-8th grades). Participants were divided into three groups: (a) Learning difficulties (LD) of the pedagogical order formed by 7 children; (b) Developmental dyslexia (DD) with 8 children; (c) Without learning difficulties - Control (C) with 8 children.

Children in groups LD and DD were selected from referrals to the Clinic of Neuro-Learning Disabilities, University of Campinas Teaching Hospital. Initially, the children underwent diagnostic evaluation performed by a multidisciplinary team and were included in the study after closing the diagnosis. The criteria for inclusion in these groups were as follows: signing the consent form by the parents; presenting an intellectual level as expected, i.e., intelligence quotient (IQ) above 80; absence of sensory or motor deficits; not using psychotropic medication and having no neurological symptoms.

Children in group C, who were selected from the appointment of teachers at a school in the metropolitan region of Campinas/SP, did not have learning difficulties and poor academic performance. Children were selected accordingly, matched for age and sex with other groups and assessed in the school context. The criteria for inclusion in the group were as follows: a consent form signed by parents; no complaints about learning difficulties and satisfactory academic performance; no sensory or motor deficits, psychotropic medication and neurological symptoms.

Instruments

Cancellation Tests (CT; Lima, Travaini, & Ciasca, 2009b). This instrument assesses sustained visual-spatial attention. We used two versions: (a) Geometric Figures (CT-GF): composed of a sheet with pseudo-random sequence, i.e., pseudo-random simple geometrical figures, in which the child had to mark all found circles (a total of 92) as fast as he could; (b) Letters in Row (CT-LR): composed of lyric sheets distributed at random, in which the child had to check all the letters "A" (a total of

60) as fast as he could. For both versions, there was no set time limit to perform the tasks. Scores were obtained: (a) Time: time in seconds that the child needs to perform the task; (b) Omission Errors: number of target stimuli that the child did not check; (c) Addition Errors: number of non-target stimuli the child checked.

Trail Making Test A/B (TMT-A/B; Lima et al., 2009b). Part A assesses visual sustained attention and is composed of a sheet with circles numbered 1 to 25, and the child was randomly assigned to draw a line connecting the sequence of numbers as fast as he could. Scores were obtained: (a) Time: time in seconds to perform the task and (b) Number of Errors: number of links wrongly sequenced. Part B assesses mental flexibility and is composed of circles with numbers and letters. The child should draw a line alternately connecting the circles with numbers and letters, for example: 1-A-2-B-3-C, following the correct alphabetical and numerical order. Scores were obtained: (a) Time: time in seconds; (b) The number of sequencing errors: number of links with the wrong sequence of letters or numbers; and (c) Switching Errors: the number of times in which letters were alternated with numbers. Before collecting the data, it was verified whether the children properly recognized numbers and letters randomly and sequentially.

Stroop Color Word Test (SCWT; Lima et al., 2009b). This test evaluates the ability of inhibitory control and selective visual attention. We used the four-color version (red, yellow, blue and green) and 24 stimuli in each of three parts: (a) "Color Card" (SCWT-C): with squares in four colors, using pseudorandom order; the child had to name the colors as quickly as possible; (b) "Card Words" (SCWT-W): with color names printed in colors corresponding to which the child had to name; (c) "Card Color-Word "(SCWT-CW): with names of colors, but printed in incongruent colors, for example, the word "green" printed in blue and the child had to say the name of the color and not read the word. Scores were obtained for time and errors for each of the cards, and additional scores were calculated: (a) Facilitation: the facilitation process obtained from the presentation of congruent stimuli. The score is obtained by subtracting time (facilitation-time) and error (facilitate-errors) scores: "color card" – "card words"; (b) Interference: which represents the "stroop effect" due to the incongruous situation of the test. The score is obtained by subtracting time (interference-time) and error (interference-errors) scores: "color-word card" – "color card".

Tower of London (TOL; Lima et al., 2009b). The TOL assesses the mental ability to plan and consists of a wooden base with three vertical pins and three colored circles with a hole in the center to allow the groove on the pin. The goal is to rearrange the position of the circles from a fixed initial order to get different orders defined by the evaluator. Ten items showed increasing degree of difficulty depending on the number of moves needed to reach the final position. For each item, the examiner placed the circles in early position and then in final position; the child had to play using the fewest possible moves. The scores for each item could range from 1-3 points. The final score was expressed as the sum of scores for each item.

Procedures

The study was approved by the Research Ethics Committee of the Faculty of Medical Sciences – University of Campinas (FCM-Unicamp). The children were assessed individually by a single examiner in the rooms of the Outpatient Clinic of Neuro-Learning Difficulties or school, according to the group, and after parents signing the WIC. The tests were applied in the following sequence: cancellation test, trail making test, stroop color word test and the tower of London.

After the evaluations, the data were tabulated and went through descriptive statistics (measures of central tendency and dispersion) and inferential statistics (*Chi-square* test, student's *t*-test and analysis of variance), using SPSS (Statistical Package for Social Sciences) and adopting a significance level of 5%, i.e., $p < .05$.

Results

Group LD was composed of seven school children – five boys and two girls – attending the 3rd to the 7th grades. The DD and C groups were composed of eight school children – six boys and two girls – attending the 3rd to the 7th grades. The chi-square results indicated that there was no difference in frequency distribution between genders ($p = .984$). Analysis of variance (ANOVA) also indicated no differences among the average ages of the groups ($p = .133$) (Table 1).

Table 1
Sample Characterization

Variable	LD *(n=7)*	DD *(n=8)*	C *(n=8)*	*P-value*
Gender				
Male	5 (71.4%)	6 (75%)	6 (75%)	.984[a]
Female	2 (28.6%)	2 (25%)	2 (25%)	
Age				
Maximum - Minimum	9-14	9-14	9-13	
M (*SD*)	11.0 (1.85)	11.6 (1.99)	9.90 (0.64)	.133[b]

Note. [a] *Chi-square* test; [b] ANOVA.

In order to compare the performance of the groups, it was initially used descriptive statistics for the average scores of the tests used in relation to study groups; afterwards, ANOVA was conducted to compare mean scores between the groups. The test results can be seen in Table 2.

Table 2
Comparison of Average Test Scores among Groups and ANOVA Results, including F and p Values and Bonferrori Post Hoc Comparison

Scores	*Groups*			*F*	*P-value*	*Post hoc comparison*
	LD	DD	C			
CT - GF - Addition errors	.00	.00	.00	-	-	DD=LD; DD=C
CT - GF - Omission errors	.86	.00	.13	5.47	.01**	DD<LD; DD=C
CT - GF - Time	96.13	114.14	70.13	7.07	.00**	DD>LD; DD>C
CT - LR - Addition errors	.00	.00	.00	-	-	DD=LD; DD=C
CT - LR - Omission errors	3.43	3.13	.88	2.33	.12	DD=LD; DD=C
CT - LR - Time	141.43	139.00	116.25	1.05	.36	DD=LD; DD=C
TMT-A - Errors	.00	.38	.00	.93	.41	DD=LD; DD=C
TMT-A - Time	57.14	62.63	36.50	4.20	.03*	DD>LD; DD>C
TMT-B - Switching errors	.71	1.88	.13	3.07	.06	DD=LD; DD=C
TMT-B - Sequencing errors	1.00	.88	.13	1.17	.33	DD=LD; DD=C
TMT-B - Time	155.00	174.50	92.75	7.24	.00**	DD=LD; DD>C
SCWT-C - Errors	.57	1.63	.00	14.29	.00**	DD>LD; DD>C
SCWT-C - Time	19.00	23.25	16.25	4.70	.02*	DD>LD; DD>C
SCWT-W - Errors	1.00	.50	.00	2.67	.09	DD=LD; DD=C
SCWT-W - Time	18.29	20.25	14.38	2.93	.07	DD=LD; DD=C
SCWT-CW - Errors	4.71	6.38	.38	10.82	.00**	DD>LD; DD>C
SCWT-CW - Time	43.00	51.13	28.13	5.33	.01**	DD>LD; DD>C
SCWT - Facilitation errors	-.43	1.13	.00	4.78	.02*	DD>LD; DD>C
SCWT - Facilitation time	.43	3.00	1.88	.56	.57	DD=LD; DD=C
SCWT - Interference errors	3.57	4.75	.38	5.00	.01**	DD>LD; DD>C
SCWT - Interference time	19.43	27.88	11.88	2.89	.07	DD=LD; DD=C
TOL	20.57	20.75	20.88	.20	.98	DD=LD; DD=C

* *p*<.05, ***p*<.01.

Table 2 shows that the groups differed significantly in the following scores: cancellation test (GF) – omission errors and time; trail making test-A/B – time; SCWT/C – errors and time; SCWT/CW – errors and time; SCWT (facilitation-errors); SCWT (interference-errors). No comparisons were made between scores of errors by adding the cancellation test (GF and LR), because the groups did not show such errors.

Post-hoc comparisons with the Bonferrori test scores indicated that: according to cancellation test (GF) – time and omission errors; trail making test-A – time; SCWT-C – errors and time; SCWT/CW – errors and time; SCWT (facilitation-errors); SCWT (interference-errors), the DD group had higher scores than the other two groups. Regarding the score in the trail making test-B – time, the group with dyslexia had statistically similar scores to those with difficulties at school, but had higher scores than the control.

Discussion and Concluding Remarks

Based on the results, we found performance differences among groups in different evaluations. Regarding sustained visual attention tests, the group of dyslexic children showed higher scores, especially scores on time cancellation tests (geometric figures) and trail making test-A. In the case of CT-GF, in addition to increased solving time, also had greater number of omission errors. This test presented figures arranged randomly on the paper, so that the child needed more visual tracking capabilities to find and point the targeted stimuli, in this case the circles.

The result suggests that children with dyslexia had difficulties in tracking, requiring a greater solving time, which increased the number of errors. The results also corroborate the findings in the literature that indicate that dyslexics showed slower response pattern in visual-spatial attention tasks, in which cognitive resources are recruited for visual tracking (Facoetti et al., 2000; Heiervang & Hugdahl, 2003).

Hari and Renvall (2001) explained these characteristics of attention in dyslexic individuals by the theory of "slugging attentional shifting", in which the processing of a sequence of stimuli is hampered by slow attentional capture, as well as increased time of reaction. According to the authors, changes may accompany the attentional deficit in phonological processing, which is the most accepted theory to explain the deficits observed in dyslexia.

Concerning the performance on tests of executive functions, children with dyslexia showed higher scores than other groups in the stroop color word test/ color card (errors and time), card color-word (errors and time) and the facilitation and interference score errors, which measure the ability of inhibitory control.

The performance of children with dyslexia and analysis of the stroop interference is already being discussed in the literature. With the damage to performance color card, a task that involves naming the color, you can compare it with another test called rapid automatized naming – RAN; both are auto-naming tasks. RAN has been associated with speed of access to mental lexicon, and studies indicate that dyslexics have more time to perform tasks such as naming colors, digits, letters and objects (Capellini, Ferreira, Salgado, & Ciasca, 2007). The performance also allows RAN to infer perception and sequencing attentional functions (Schatschneider, Carlson, Francis, Foorman, & Fletcher, 2002) and has been indicated as a predictor of reading performance (Cardoso-Martins & Pennington, 2001; Krasowicz-Kupis, Borkowski, & Pietras, 2009). Salgado, Lima and Ciasca (2008) also indicated that lexical access component involves attentional and inhibitory control, as evidenced by correlations between the scores of stroop and RAN in children with dyslexia.

In card color/word, the actual score of the stroop interference is more evident than the effect of interference, also called "stroop effect". This card is presented in an incongruous situation in which we have the name of a color printed in another color, for example, the word "red" printed in color "yellow". The child should name the color, but not read the word. In the example above, it should say "yellow."

As stated by MacLeod and MacDonald (2000), the printed word interferes with naming the color, since under the brain processing point of view, word reading is more automatic than color naming. Thus, the individual should inhibit the automatic response of reading the word to issue a controlled response of color naming, as instructed by the evaluator.

In the case of individuals with dyslexia, because they had difficulties in reading, one would expect that the interference effect was smaller; however, the results indicated increase in time and error scores. One hypothesis for this result is that some level of automatic processing of the word must occur, as shown by Everatt et al. (1997). Another alternative is to consider the very difficult lexical access when naming colors associated with automation deficit.

In part B of trail making test, which measures mental flexibility, the time score of children with dyslexia did not differ from the group with school difficulties; however, it was higher than in the control group. In the literature, the results of dyslexic children in TMT have been contradictory. Närhi, Räsänen, Metsäpelto and Ahonen (1997) described differences between children with dyslexia and without difficulties in TMT-A; however, differences were observed in TMT-B time scores. In the study by Reiter et al. (2005), despite having higher time and error scores, children with dyslexia did not differ statistically from the control group. The use of different versions of the tests may help in understanding contradictory data.

In the evaluation of capacity planning and troubleshooting by the tower of London, there were no differences among the three groups as well. In the study by Reiter et al. (2005), it was used the TOL version by Shallice (1982). The authors found significant differences between dyslexics and controls just in time for score, but not in the number of hits, i.e., children took more time solving the test but had an effective performance. In this study, we used an adapted version of Shallice (1982) and did not compute the solving time but only the total score. Thus, our score results were similar to those obtained by those authors.

Another aspect we should consider is the performance of this test; in addition to being a planning measure, it also involves logical-mathematical ability that is not compromised in children with dyslexia. Therefore, we can indicate that, despite the need for a longer time for response organization and planning, which involves executive functioning and processing speed, children with dyslexia show satisfactory performance.

Despite the limited number of children in groups, making it difficult to generalize the findings, this study suggests some characteristics of children with dyslexia when it comes to attention and executive functioning. We found that dyslexics may show changes in these functions and that such damage may accompany the core deficit in the phonological component of language. And given the lack of studies approaching this subject, further researches are needed to understand the relationship between phonological processing and attentional and executive aspects of dyslexia, as well as how these aspects can support such written language (reading/writing).

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