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Attentional and Executive Deficits in Brazilian Children with Developmental Dyslexia*

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The present study aims to compare the performance between Brazilian children with Developmental Dyslexia (DD) and children without learning difficulties on tests of attention and Executive Functions. The study sample consists of study group (20 subjects) attending the Learning Disability clinic of University Hospital and control group (20 subjects) from public school in Campinas-SP. The instruments utilized were: WISC-III factor indexes and subtests, cancellation test, Trail Making Test, Stroop Color Word Test, Tower of London, Wisconsin Card Sorting Test and verbal fluency test. The results revealed differences between groups in scores of different instruments. The findings suggest that children with dyslexia have difficulties in performing visuospatial and auditive attention tasks, as well as tasks involving different components of executive functions, such as flexibility, inhibitory control, strategy use, working memory and verbal fluency. Such changes may be part of dyslexia and accompany the core deficit in the phonological component of language.

Keywords: Neuropsychology; Dyslexia; Attention; Executive Function

Introduction

Developmental Dyslexia (DD) is a neurobiological disorder characterized by difficulties in acquiring reading and/or written skills as a result of deficit in the phonological component of language. These characteristics are unexpected when considering the level of intelligence and effective instruction in the classroom (Lyon, Shaywitz, & Shaywitz, 2003). According to the International Statistical Classification of Diseases and Related Health Problems (ICD-10) (WHO, 2008), the main diagnostic criteria of DD are level of intelligence within the average, absence of uncorrected sensory changes, absence of others, neurological and/or psychiatric disorders, as well as below average performance in reading/writing.

Developmental Dyslexia is accompanied by impairments in different cognitive functions such as visuospatial attention and Executive Functions (EF) (Ruffino *et al*., 2010; Franceschini *et al*., 2012; Lima, Salgado-Azoni, & Ciasca, 2012). Researches have shown that children with DD exhibit inefficient visuospatial distribution of attention engagement (Ruffino *et al*., 2010). The difficulty is also evident for the recruitment of cognitive resources necessary for performance of complex tasks involving reaction time and reading fluency (Heiervang & Hugdahl, 2003). In visual attention tasks using reaction time measures, children with DD show higher resolution time (Facoetti *et al*., 2010).

Previous studies proposed that the processing of a rapid sequence of stimuli in all sensory modalities was hampered by the slow attentional capture and increased reaction time (Hari & Renvall, 2001; Facoetti *et al*., 2010). Another work has shown impairment in the ability to rapidly change attentional skills from a target stimulus to another one. The impairment in this ability may affect the allocation of attentional resources and processing time and sequence of graphemes for reading (Visser, Boden, & Giaschi, 2004). These characteristics may accompany deficits in phonological processing (Hari & Renvall, 2001; Facoetti *et al*., 2010).

Some authors suggest that the deficit of visual attention in DD may be specific to the characteristics of the presented stimuli, showing significant only in the processing of verbal material (letters and digits), but not with non-verbal (symbols) (Marzocchi, Ornaghi, & Barboglio, 2009; Savill & Thierry, 2012). Recently, Savill and Thierry (2012) found gaps in attentional engagement with tasks related to phonological demands (spelling and reading).

Although most authors agree that phonological deficit is central in dyslexia (Lyon *et al*., 2003; WHO, 2008; Lima *et al*., 2012), some others have proposed the opposite. According to this view, attentional mechanisms can control the dorsal visual stream and are fundamental to the sequential tracking of letters. Thus, the deficit in this process leads to a cascade of effects, including impairments in visual processing of graphemes, grapheme-phoneme conversion, and finally, in phonological awareness (Vidyasagar & Pammer, 2009). In contrast, other authors do not point to evidence that the deficit in phonological processing is caused by attentional dysfunction (Heim *et al*., 2010).

Concerning the EF, due to its multifunctional nature, it has been suggested that there is impairment of only some aspects

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(Reiter *et al*., 2005). Previous studies show that when compared with proficient readers, children with DD show impairments in performance of instruments that assess inhibitory control (Everatt *et al*., 1997; Van Der Sluis, De Jong, & Van Der Lij, 2004; Reiter *et al*., 2005), use of cognitive strategies (Helland & Asbjornsen, 2000), verbal working memory (Brosnan *et al*., 2002; Reiter *et al*., 2005) and other subcomponents of working memory (Schuchardt, Maehler, & Hasselhorn, 2008). In planning tasks, there are no differences between DD and control subjects in total scores; however, such differences are observed in time to perform the task (Reiter *et al*., 2005).

Therefore, this study aimed to compare the performance between children with DD and children without learning difficulties on tests of attention and EF. We tested the hypothesis that children with DD would exhibit worse performance than children without learning disabilities in the instruments used.

Method

Subjects

The study was approved by the Research Ethics Committee, University of Campinas (FCM-Unicamp) (protocol n. 648/2007). The study included a total of 40 children of both genders (53% boys, 48% girls), aged between 7 - 11 years, average age of 9.38 (SD = 1.08) years, attending the 1^{st}-5th grades of elementary school.

Two groups were formed from the total sample. The group with Developmental Dyslexia (DG) was selected from referrals to the Learning Disability clinic of University Hospital. The children underwent interdisciplinary assessment (neuropsychology, speech pathology, education, neurology and psychiatry) and 20 were included in the study diagnosed with developmental dyslexia. The diagnosis was followed the criteria of the Diagnostic and Statistical Manual of Mental Disorders (DSM-IV-TR) (APA, 2002), International Classification of Diseases (ICD-10) (WHO, 2008) and clinical characteristics: IQ ≥ 80 assessed by Wechsler Intelligence Scale for Children-WISC-III (Wechsler, 2002); performance 2SDs below age on measures of reading/writing and phonological processing: speed reading, reading accuracy, written under dictation, written spontaneously, rapid automatized naming test (RAN), phonological awareness test and phonological working memory test.

The DG was formed by 20 children, 55% of boys and 45% of girls, averaging 9.70 years old (SD = 0.98), 1^{st} - 5th grade. The inclusion and exclusion criteria were as follows: parent authorization by consent term; submit intelligence quotient (IQ) within the normal range, *i.e*., ≥80, according to WISC-III (Wechsler, 2002); not making use of psychotropic medicine and not presenting other neurological symptoms; does not provide criteria for Attention Deficit Hyperactivity Disorder (ADHD).

The control group (CG) was selected from public school in Campinas-SP, comprising 20 children without complaints of learning difficulties and/or attention, proficient readers, 50% of boys, average age of 9.05 years (SD=1.10), 1^{st} - 4^{th} grade. The inclusion and exclusion criteria were as follows: parent authorization by consent term; present IQ ≥ 80, as WISC-III (Wechsler, 2002); have been nominated by teachers for not presenting complaints of difficulties in learning and have reading level expected for their age; not make use of psychotropic medication, not show any type of sensory impairment and neurological development delay.

Instruments

All participants were evaluated by the same neuropsychologist, using the instruments described below.

Wechsler Intelligence Scale for Children (WISC-III) (Wechsler, 2002). Clinical instrument that assessed intellectual ability and different cognitive abilities. For the study we used the full intelligence quotient (IQ), verbal IQ and performance IQ.

WISC-III subtests (Wechsler, 2002): Coding (Cod), Symbol-Search (SS), Arithmetic (Arit) and Digits (Dig). This subtests assessed attention in visual (Cod and SS) and auditory (Arit and Dig) modalities. For analysis, we used the weighted scores from these subtests.

WISC-III indexes (Wechsler, 2002) Distraction Resistance (DRI) and Speed of Processing (PSI). Indexes related to visuospatial and auditory sustained attention, obtained from WISC-III subtests. IQs were considered measures of this index factor.

TC (Lezak, 1995; Lima *et al*., 2012). This test evaluated visuospatial attention to visual material, visual scanning velocity and processing. We used two versions: Geometric Figures (CT-GF) and Row of Letters (CT-LR). Scores were used: time and errors of omission.

Trail Making Test (TMT-A/B) (Lezak, 1995; Lima *et al*., 2012). Part A assesses visual sustained attention and visual scanning ability. Part B assessed mental flexibility and attention-switching capacity. The scores were obtained: time, switching errors and sequencing errors.

Stroop Color-Word Test (SCWT) (Lezak, 1995; Lima *et al*., 2012). This test evaluated the inhibitory control (ability to inhibit automatic response to the issue of controlled response) and visual selective attention (selection between relevant and irrelevant information). Three cards were used: Color (neutral condition), Word (congruent condition) and Color-Word (incongruent condition). The scores were obtained: time and errors.

Tower of London (ToL) (Lezak, 1995; Lima *et al*., 2012). This test evaluated the mental ability to plan and logical reasoning. It was considered the total score of correct answers.

Wisconsin Card Sorting Test (WCST) (Heaton *et al*., 2005). WCST evaluated ability to use and modify strategies using feedback environment. We considered the following scores: trials to complete the first category (WCST-TC); number of completed categories (WCST-CC); number of tests administered (WCST-TA); Total number of successes (WCST-NS); Total number of errors (WCST-NE) and error percentage (WCST-EP).

Digits-Backward (Wechsler, 2002). Part of digits of the WISC-III subtest that assessed working memory for verbal material.

Verbal fluency test (FAS) (Lezak, 1995). FAS evaluated the capacity of words verbally. We used the phonological semantic versions and found the average scores for each version.

Procedure

All participants were assessed individually by a single examiner, according to specific instructions for each instrument in the rooms of the Outpatient Neuro-Learning Difficulties or school, according to the group and after parents signing the consent inform. Statistical analysis was performed using the program SPSS Statistics 20.0 for Windows. To compare means between groups we used the Mann-Whitney nonparametric test.

Additionally was calculated measure of effect size (Cohen's d).

Results

The groups had IQ with scores within the normal range. Verbal, performance and full IQ scores were higher than average in the CG and within average in the DG. Mean WISC-III index is presented in **Table 1**. **Table 2** presents the results of comparisons between groups with regard to the instruments to assess attention. Comparisons between the groups for the assessment of executive functions are shown in **Table 3**.

Discussion

This study aimed to compare the performance between children with DD and children without learning difficulties on tests of attention and EF. The diagnosis of DD requires the estimate of the general intellectual ability, excluding the possibility of explaining the reading difficulty as a lowering of intelligence (APA, 2002). The DG have the intellectual level at or above the mean for age, as noted in our results. Although both groups were classified in normal level, DG showed verbal, performance and full IQs less than the CG. This result was also obtained in the comparison of mean IQs, in which dyslexics scored lower in all IQs. Regarding the DG results, our findings are similar to those obtained in the study by De Clercq-Quaegebeur *et al*. (2010).

In the attentional evaluation, DG had lower scores in WISC-III subtests. This results suggests that children with DD have difficulties in tasks involving visuospatial attention skills, quantitative reasoning, immediate memory and processing speed. Other studies also found lower performance of children with DD in digit subtest (WISC) or other versions of the digit span test (Helland & Asbjornsen, 2000; Clercq-Quaegebeur *et al*. 2010). Although the digits subtest requiring sustained attention for its performance, the response elaboration requires short-term memory. Furthermore, the weighted score is obtained by summing the order forward and backwards, and the latter is more closely with verbal working memory. With this in mind, the impairment of individuals with DD on this task may suggest difficulties in the mentioned aspects.

The Distraction Resistance Index (RDI) is commonly considered an objective measure of attention due to its name. However, your subtests (arithmetic and digits) also require other skills such as reasoning, numerical knowledge and memory (Lima *et al*., 2012). In other hand, the subtests of Processing Speed Index (PSI) are measure more objective of visual sustained attention, despite the engagement with the visuomotor ability, visual screening graph motor rapid and repetitive response. However, this aspect does not differentiate them from other attentional assessment tools. Thus, our results suggest that children with DD have difficulties in visuospatial and auditory sustained attention, as well as in processing speed.

Other authors have been indicated that individuals with DD show changes in processing speed as children with ADHD (Shanaham *et al*., 2006). However, other studies contradict this

Table 1.
Comparison of groups in the WISC-III.

Scores	Controls	Dyslexia	p	d	ES
	M (SD)				
Verbal IQ	118.30 (11.41)	104.05 (17.97)	<0.01*	−0.95*	0.43
Performance IQ	113.50 (14.86)	105.55 (12.76)	<0.05*	−0.57*	−0.28
Full IQ	117.45 (12.64)	105.05 (15.73)	<0.05*	−0.87*	−0.40

IQ: intelligence quotient; M(SD): mean (standard deviation); p: significance level; d: Cohen's d; ES: effect-size.

Table 2.
Comparison of groups using instruments of attention.

Scores	Controls	Dyslexia	p	d	ES
	M (SD)				
Cod	11.80 (2.40)	10.70 (2.11)	>0.05	−0.49*	−0.24
SS	13.10 (1.48)	10.65 (1.69)	<0.01*	−1.54*	−0.61
Arith	13.00 (1.81)	10.65 (2.70)	<0.01*	−1.02*	−0.46
Dig	12.70 (3.26)	8.95 (1.85)	<0.01*	−1.41*	−0.58
DRI	113.85 (13.48)	97.55 (11.72)	<0.01*	−1.30*	−0.54
PSI	110.45 (13.02)	102.45 (8.76)	<0.05*	−0.72*	−0.34
CT-GF/time	92.35 (24.46)	96.55 (18.48)	>0.05	0.19	0.07
CT-GF/omission errors	0.60 (0.94)	1.80 (2.40)	>0.05	0.66*	0.31
CT-LR/time	152.05 (64.25)	151.60 (50.12)	>0.05	−0.00	−0.00
CT-LR/omission errors	1.60 (2.56)	5.75 (4.92)	<0.01*	1.06*	0.47

Cod: coding; SS: symbol search; Arith: arithmetic; Dig: digits; DRI: distraction resistence index; PSI: processing speed index; CT-GF: cancellation test—geometric figures; CT-LR: cancellation test—letters in row; TMT: trail making test; M(SD): mean (standard deviation); p: significance level; d: Cohen's d; ES: effect-size.

Table 3.
Comparison of groups using instruments of executive functions.

Scores	Controls	Dyslexia	p	d	ES
	M(SD)				
TMT-A/time	60.05 (25.05)	58.40 (17.41)	>0.05	−0.08	−0.04
TMT-A/errors	0.00 (0.00)	0.25 (0.79)	>0.05	0.45*	0.22
TMT-B/time	143.80 (76.47)	193.85 (97.30)	>0.05	0.57*	0.27
TMT-B/switching errors	0.00 (0.00)	1.10 (1.74)	<0.01*	0.89*	0.41
TMT-B/sequencing errors	0.10 (0.45)	1.05 (1.23)	<0.01*	1.03*	0.46
SCWT-color/time	16.10 (2.47)	22.95 (4.01)	<0.01*	2.06*	0.72
SCWT-color/errors	0.25 (0.55)	0.80 (0.77)	<0.05*	0.82*	0.38
SCWT-word/time	11.25 (1.71)	20.65 (5.36)	<0.01*	2.36*	0.76
SCWT-word/errors	0.00 (0.00)	0.85 (0.93)	<0.01*	1.29*	0.54
SCWT-color word/time	37.00 (8.31)	46.55 (20.20)	>0.05	0.62*	0.30
SCWT-color word/errors	2.50 (2.21)	4.60 (3.27)	<0.05*	0.75*	0.35
ToL	20.97 (2.58)	19.55 (3.12)	>0.05	−0.50*	−0.24
WCST-TC	14.60 (10.29)	25.50 (35.68)	<0.05*	0.42*	0.20
WCST-CC	5.50 (1.41)	3.70 (2.11)	<0.05*	−1.00*	−0.45
WCST-TA	108.30 (20.49)	119.50 (15.52)	>0.05	0.62*	0.29
WCST-NS	71.50 (9.06)	62.85 (16.47)	>0.05	−0.65*	−0.31
WCST-NE	118.60 (12.93)	101.75 (19.34)	<0.05*	−1.02*	−0.46
WCST-EP	117.55 (12.01)	101.75 (18.90)	<0.05*	−1.00*	−0.47
Digits	4.97 (1.90)	3.03 (.84)	<0.01*	−1.32*	−0.55
FAS-fonology	8.71 (2.14)	6.23 (2.12)	<0.01*	−1.16*	−0.50
FAS-semantic	11.14 (2.01)	10.75 (2.83)	>0.05	−0.15	−0.08

TMT: trail making test; SCWT: stroop color word test; ToL: tower of London; WCST-TC: Wisconsin card sorting test—trials to complete the first category; WCST-CC: completed category; WCST-TA: tests administered; WCST-NS: number of successes; WCST-NE: number of errors; WCST-EP: error percentage; M(SD): mean (standard deviation); p: significance level; d: Cohen's d; ES: effect-size.

position. Bonifacci and Snowling (2008) found that the performance of children with DD was similar to children with borderline intelligence level on tasks of processing speed. De Clercq-Quaegebeur *et al*. (2010) found deficits in the PSI of WISC-IV, but the result was explained only by the performance in the "coding" and not the "symbol search", which to the authors does not indicate lowering overall processing speed. However, the cited studies used different methods: PSI of the WISC-IV (De Clercq-Quaegebeur *et al*., 2010) and computerized measures with reaction time using tracking of numbers and letters (Bonifacci & Snowling, 2008).

We suggest that the specificity and diversity of stimulus materials (visual and auditory modalities, letters, numbers, shapes) and types of involved responses (verbal-motor output*)* can lead to different results.

There were differences between groups in omission errors of cancelattion tests. We think that, despite of the DG having demonstrated adequate time resolution, the quality of attentional performance and recruitment resources to control this performance was lower, expressed by the large number of errors. In general, the literature indicates that children with DD have difficulty in serial visual tracking tests (as cancellation tests), by reducing the number of items simultaneously processed (Hari & Renvall, 2001). Another aspect to be cited is that this performance occurred mainly in the TC - letters in row, which has verbal stimuli. These data corroborate with the attentional characteristics presented in previous studies, which describe that attentional deficits may be specific to verbal stimulus (Marzocchi *et al*., 2009; Savill & Thierry, 2012).

Considering different executive functioning capabilities, children with DD have impaired performance on different components. Previous studies with DD showed damaged performance on the TMT. Our results show significative differences between groups in scores of time (only Part B) and errors (Parts A and B). In TMT - Part A, there were differences in error score, using only magnitude measure (Cohen's d). Others studies using traditional statistics this difference was not obtained (Reiter *et al*., 2005; Närhi *et al*., 2008; Lima *et al*., 2012).

In TMT-Part E, which involves alternating numerical and alphabetical sequence, our result was similar to that obtained by others studies (Reiter *et al*., 2005; Närhi *et al*., 2008; Lima *et al*., 2012), so that the children of DG showed higher scores and time errors.

In the assessment of inhibitory control by SCWT, DG had more time to solve the three cards (Color, Word and Color-Word) and, consequently, a greater number of errors. The results suggest impaired performance in inhibitory control, as indicated by other studies (Everatt *et al*., 1997; Brosnan *et al*., 2002; Reiter *et al*., 2005). Everatt *et al*. (1997) suggest that, to resolve Stroop test, some level of word processing should be possible, causing problems in automatization and control responses, *i.e*., color naming. Thus, alterations in lexical access and in their attentional demands may serve as a basis for understanding the performance of individuals with DD in that test.

The groups also differ when considering the ToL, using Cohen's d. Other study found no score differences between children with DD and good readers (Lima *et al*., 2012) regarding the correct answers, but at the time of planning (Reiter *et al*., 2005). Besides planning, the ToL also involves logical mathematical reasoning, which is not compromised in children with DD (Lima *et al*., 2012). Thus, we can suggest that, despite the need for a longer time for the organization and planning of response, which involves others executive functions and processing speed, children with DD can show satisfactory performance.

Regarding WCST, individuals with DD had more trials to solve the first category of WCST (average of 25 trials); they also completed fewer categories (average of three categories), *i.e*., they finished 128 completed trials without completed the six categories. Consequently, their scores were higher in the total number of errors/percentage of errors and lower scores of correct trials. Contradictory results are found in the literature. Some studies indicate that individuals with DD have higher percentage of perseverative errors (Marzocchi *et al*., 2009), and while others studies point out that they complete fewer categories, but do not show more perseverative errors (Menghini *et al*., 2010) Using the reduced and adapted version of the WCST (modified card sorting test), it was found that children with DD had fewer errors and perseverations. The authors explained that this result may be due to the familiarity of dyslexics with testing procedures in diagnostic situations (Reiter *et al*., 2005). This explanation does not seem more plausible than the possibility of amendments to cognitive ability assessed by the instrument. Moreover, other study (Marzocchi *et al*., 2009) using the original version of the WCST indicate otherwise, coinciding with our findings.

We used the Digits Backward (WISC-III) scores as a measure of verbal working memory, and DG scored lowered when compared with CG. There is evidence of deficits in the resolution of the forward and backward digit span in children with DD (Jeffries & Everatt, 2004). Other studies indicate that instruments that assess phonological working memory can be used to distinguish children with dyslexia and control problems because they reflect the level of phonological representation (Jeffries & Everatt, 2004; Reiter *et al*., 2005; Schuchardt *et al*., 2008; De Clercq-Quaegebeur *et al*., 2010).

The FAS was used in our study to measure verbal fluency. Initially, according to our results, both groups showed semantic category scores greater than the phonological category. This can be considered normal due to the greater ease of semantic test. However, the groups only differed in phonological category. Previous studies described impairments in children with DD when performing verbal fluency tests, with the recovery of fewer words, especially in phonological category (Reiter *et al*., 2005; Marzocchi *et al*., 2009).

We suggest that the results described above may not be part of the core deficit in DD (Lima *et al*., 2012), but accompany the deficit in the phonological component of language. According to the literature, the attentional posterior system of superior parietal cortex, mediated by the magnocellular processing, can support impairments in visuospatial attention in DD (Facoetti *et al*., 2010; Franceschini *et al*., 2012). In addition, top-down executive control mechanisms, mediated by different regions of the frontal lobe, may help explain deficits in executive functioning skills. Thus, addition of language, DD can be considered a disorder of multiple deficits and at different levels, affecting directly affect reading and writing.

Conclusion

The results suggest that children with Developmental Dyslexia have difficulties in visuospatial attention tasks and different components of Executive Functions (flexibility, inhibitory control, strategy use, working memory and verbal fluency), confirming the hypothesis of the study. More studies on such cognitive skills can assist in planning the evaluation, as well as the development of neuropsychological intervention programs, as described by Lorusso, Facoetti and Bakker (2010).

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