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Perceptual Visuo-Motor Skills and Handwriting Production of Children With Learning Disabilities

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This study aimed to explore the performance of the perceptual-visuomotor skills and the production of handwriting in children with Learning Disabilities. A total of 56 children participated, being a convenience sample, of both sexes, average age of eight years old, from 3rd to 5th grade level of Elementary School. The children were divided into the following groups: GI (28 children diagnosed with Learning Disabilities); GII (28 children with good academic performance, paired with GI in relation to chronological age and sex). They were evaluated individually in dysgraphic scale, visual perception development test, and fine motor evaluation. Data analysis was performed. There was a significant difference between GI and GII for the subtests of eye-hand coordination, copying, visual closure, fine motor precision, and fine manual control tests. They had difference between the groups for handwriting performance in descending and/or ascending subtests, irregularity of dimension, poor forms, and total score of Dysgraphia Scale. The results presented in this study indicate that children with Learning Disabilities can manifest significant visomotor impairment and deficit in legibility and handwriting quality, causing failures in the elaboration of sensorimotor plans that, added to the intrinsic deficit of long-term memory, result in persistent academic difficulties.

Keywords: Learning Disabilities, evaluation, handwriting, visual perception, fine motor skills, dysgraphia

Introduction

Difficulties with handwriting can interfere with the execution of composing processes during the act of writing. Having to consciously attend to handwriting processes while composing may tax the writer's processing memory, interfering with other writing processes, such as generating content and planning (Graham, Harris, & Fink, 2000). However, many children with Learning Disabilities (LD) struggle to master handwriting skills.

As described by Lyon et al. (2001), LD are not a single disability, but a general category composed of disabilities in at least one of a combination of seven skill domains such as listening, speaking, basic reading, reading comprehension, arithmetic calculation, mathematics reasoning, and written expression. Disabilities in these areas occur together frequently and can also be accompanied by emotional, social, and behavioral

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disabilities and problems involving spatial orientation and motor abilities (Hammill, 1990). Because they have persistent manifestations throughout life (Cortiella & Horowitz, 2014; Hammill, 1990; Lyon et al., 2001), writing is a common means of communication and expression present not only in the academic and occupational environment, but also in daily life activities. Thus, despite all technological and digital advances, handwriting is still a necessity to be accomplished, and for its domain, it requires visual and fine motor skills, which may be impaired in children with LD. Hence, such aspects reinforce the continued need to investigate the visuomotor profile of children with LD.

Visuomotor integration is important for school activities, and it is through this, that children can copy, produce and reproduce letters and numbers isolated and in sequences, write words and texts quickly and effectively (Brown & Rodger, 2008; Brown, Unsworth, & Lyons, 2009). Failure in visuomotor integration leads to slow and illegible handwriting, impacting academic performance directly (Crawford & Dewey, 2008; Martin, Piek, Baynam, Levy, & Hay, 2010).

With academic development and practices, visuomotor perceptual information is stored in long-term memory. At the beginning, children start to perform handwriting with less sensory control and less cognitive demand (Meulenbroek & Van Galen, 1988). The movement control is improved with practices, and gestures become fast, accurate, and automatic. Automatization is, therefore, linked to an implicit motor learning resulting from complex sensorimotor associations (Halsband & Lange, 2006). In this way, an efficient motor control occurs from the internalization of the visuomotor-perception integration, and the experiences learned (Thibon, Gerber, & Kandel, 2018).

Such aspects are important for the child, since from the moment when handwriting becomes automatic, the writer does not need to direct his attention to aspects of the movement of writing, as working memory resources became available for the writing process of high level (such as, reviewing a written text), thus guaranteeing a good academic performance (Thibon, Gerber, & Kandel, 2018; Germano & Capellini, 2019). Therefore, the effectiveness of programming fast and accurate movements occurs as the tactile-perceptual information adjusts to the visual information, due to the integrity of cortical structures (Feder & Majnemer, 2007; Khayat, Pooresmaeili, & Roelfsema, 2009; Huberle, Driver, & Karnath, 2010; Rosenblum, Aloni, & Josman, 2010).

Studies (Germano, Giaconi, & Capellini, 2016; Rosemblum, 2008) reported that children with specific Learning Disabilities (such as dyslexia) and Attentional Deficit and Hyperactive Disorders (ADHD) have flaws in fine motor coordination and changes in visual-motor perception, resulting in academic difficulties. However, studies with LD profile, especially regarding Brazilian children population, are still scarce. Since these children tend to have persistent manifestations, an interdisciplinary investigation can contribute for a better understanding of handwriting skills and its underlying components. Thus, the aim of this study was to explore the performance of the perceptual-visual-motor skills and the production of handwriting in children with Learning Disabilities.

Methods

Participants

This study was submitted and approved by the Research Ethics Committee of São Paulo State University (FFC/UNESP) under protocol number 1,841,638. All participants presented Free and Informed Consent Form signed.

A total of 56 children participated in this study, being a convenience sample, of both sexes, aged eight years and 0 months to 11 years and 11 months old (average age 8:0 years old), from 3rd to 5th year Elementary School, who attended public education in the city of Marília (state of São Paulo, Brazil). The children were divided into Group GI, composed of 28 children diagnosed with Learning Disabilities who attended the Investigation Learning Disabilities Laboratory (LIDA/UNESP-FFC/Marilia-SP), being 20 male and eight female. The participants received the diagnosis of Learning Disabilities based on standard criteria (American Psychiatric Association [APA], 2013) and attended school regularly. None of them had any history of neurological illness or brain damage. All had normal or corrected-to-normal vision and hearing. The children were submitted to an interdisciplinary screening (Germano, Reilhac, Capellini, & Valdois, 2014). They had inferior performance in relation to grade level and age for the reading, writing, and arithmetic of School Performance Test (TDE, Stein, 1994). Group II (GII) was composed of 28 children with good academic performance. Group II was paired with Group GI in relation to chronological age and sex. Children of GII had average and superior performance in relation to grade level and age for the reading, writing, and arithmetic of School Performance Test (TDE, Stein, 1994).

As exclusion criteria were adopted, the absence of Informed Consent Term signed, children with sensory deficits (hearing and/or visual impairment) and physical deficits, intellectual disabilities described in school records and/or in assessment findings neuropsychological and children who underwent some type of Speech Language Therapy, Occupational and Pedagogical Therapy remediation.

Procedures

The children were evaluated individually, in three to four sessions, with a maximum duration of 50 minutes. All were submitted to the procedures:

- Dysgraphic Scale (Lorenzini, 1993): Children were asked to write a dictation using a 2B pencil and sheet without lines and guidelines. Capitalized writing was performed, as the GI children were unable to execute the cursive letter. The evaluated items were floating lines (FL—the line is not straight, like a floating wave, based on a framework adopted); ascending/descending lines (ADL—lines go down and up on a regular basis from an adopted framework); retouched letters (RL—retouched, redone, blurred letters or parts of the letter); irregularity of dimensions (ID—improper variation in the size of the letters inside long words, with some letters reduced or elongated beyond the medial area of the letters); poor forms (PF—letters are deformed in an unsightly and improper way, unintelligible); and total for handwriting under dictation. The punctuation is made by the sum of the number of mistakes made. The procedure is validated for the Brazilian population.
- Visual Perception Development Test III-DTVP III (Hammill, Pearson, & Voress, 2014). The procedure is validated for schoolchildren aged four years to 12 years and 11 months. The protocol consists of a battery of five subtests being Eye-Hand Coordination (EH), Copying (CO), Figure-Ground (FG), Visual Closure (VC), Form Constancy (FC). The composite score generated allows the classification in relation to the General Visual Perception (GVP, composed by the summation of all subtests), Motor-Reduced Visual Perception (MRVP, composed by the subtests figure-ground, visual closure and form constancy), and Visuomotor Integration (VMI, composed of the subtests copying and eye-hand coordination). The children were classified according to the composite scores, being "very poor" (1), "poor" (2), "below average" (3), "average" (4), "above average" (5), "superior" (6), and "very superior" (7).

- Motor Evaluation of Bruininks-Oseretsky (Bruininks-Oseretsky Test of Motor Proficiency 2-BOT-2) (Bruininks & Bruininks, 2005). The procedure is validated for children aged four years to 21 years and 11 months, with different punctuation according to sex. The procedure consists of a set of tests, which assess motor areas. Only the fine motor evaluation part was used in this study, consisting of the subtests Fine Motor Precision (FMP) and Fine Motor Integration (FMI), which together form Fine Manual Control (FMC). Fine Motor Precision (FMP) task consists of activities that require precise control of fingers and hand movement. It contains activities as drawing tasks with filling in shapes, drawing lines through paths, connecting dots, and folding paper within a specified boundary. Fine Motor Integration (FMI) task consists in reproducing drawings of various geometric shapes that range in complexity (circle to overlapping pencils). It requires visual aids or guidelines. The students were classified in relation to the composite scores, being "well below average" (score 0), "below average" (1), "average" (2), "above average" (3), "well above average" (4).

Data Analysis

We gathered, calculated, and presented descriptive statistics, including group means and standard deviations. Data analysis was performed using statistical analysis of the scores, using the SPSS (Statistical Package for Social Sciences) program. The value of $p < 0.05$ was considered significant, being indicated by an asterisk (*). The Mann-Whitney test was applied in order to verify possible differences between both groups studied, for the variables of interest. Alsoa Spearman's Correlation Analysis was performed, in order to verify the degree of relationship between the variables of interest.

Results

Table 1 shows the comparison between the performance of students between GI and GII in the Visual Perception Development Test III-DTVP III (Hammill, Pearson, & Voress, 2014), and for motor assessment (BOT-2) (Bruininks & Bruininks, 2005), based on the application of the Mann-Whitney test.

Table 1
Mean, Standard Deviation (SD), and P Value in the Comparison Between Groups GI and GII for DTVP-3 and BOT-2

		GI		GII		
		Mean	*SD*	*Mean*	*SD*	*P Value*
DTVP-3	EH	138.96	28.626	164.11	14.127	< 0.001*
	CO	25.39	11.070	36.07	10.051	< 0.001*
	VC	10.93	3.868	16.07	4.109	< 0.001*
	CL_CO	2.68	1.362	4.43	1.597	< 0.001*
	CL_VC	2.25	1.005	2.89	1.227	0.014*
	CL_VMI	2.04	1.232	3.46	1.374	< 0.001*
	CL_MRVP	1.54	1.374	2.39	1.423	0.034*
	CL_GVP	1.64	1.283	2.75	1.295	0.003*
BOT-2	FMP	31.96	5.997	37.43	3.072	< 0.001*
	FMC	21.86	6.632	31.25	6.398	< 0.001*
	CL_FMP	1.39	0.629	2.32	0.905	< 0.001*
	FMI_CL	1.39	0.567	1.89	0.916	0.015*
	FMC_CL	1.25	0.799	2.14	0.525	< 0.001*

Notes. DTVP-3: CL: Classification; EH: Eye-Hand Coordination (EH); CO: Copying; VC: Visual Closure; GVP: General Visual Perception; MRVP: Motor-Reduced Visual Perception; VMI: Visual-Motor Integration. BOT-2: FMP: Fine Motor Precision; FMI: Motor Integration; FMC: Fine Manual Control. Mann-Whitney test ($p < 0.05$*).

Regarding DTVP-3 test, Table 1 showed there was a significant difference between GI and GII for the subtests of EH, CO, VC, and respective classifications performance for CO and VC; and between the classification of the composed scores of GVP (sum of all skills), RMVP (sum of visual skills exclusively), and VMI (sum of visual-motor skills—EH, CO). GI students had a lower performance compared to GII, suggesting that there are both motor and visual failures.

In addition, for BOT-2 subtests, it was possible to observe in Table 2 that there was a significant difference between GI and GII in the FMP and FMC subtests and in the performance classification for FMP, FMI, and FMC, with the GI children presenting lower average when compared to GII, indicating that children of GI might have difficulties regarding programming and executing movements with precision and fine manual control. Although no significant difference was observed for the FMI integration subtest, there was a difference for its classification. In this way, we can suggest that as the classification of FMI requires a connection between visual perception and motor programming, the FMP performance might have been influenced by visual perception, in some way, interfering in the performance of tasks that requires visual feedback, such as to make precise traces in limited spaces. Table 2 shows the comparison between the children' performances between GI and GII for the Dysgraphia Scale (Lorenzini, 1993), from the application of the Mann-Whitney test.

Table 2

Mean, Standard Deviation, and P Value in the Comparison Between GI and GII for the Dysgraphia Scale

	GI		GII		
	Mean	SD	Mean	SD	P value
DAL	0.875	0.2591	0.411	0.3614	< 0.001*
ID	1.929	0.2623	1.114	0.9083	< 0.001*
PF	0.857	0.3293	0.482	0.4808	0.002*
T	10.500	3.8754	6.429	3.7236	< 0.001*

Notes. DAL: Descending and/or Ascending Lines; ID: Irregularity of Dimension; PF: Poor Forms; T: total. Mann-Whitney test (p < 0.05*).

Table 2 shows that there was a significant difference between the groups for the DAL, ID, PF, and total score of the evaluated items. GI children showed a higher average of performance when compared to GII, suggesting that children from GI may present difficulties in handwriting due to impairments in visuomotor skills, as demonstrated in Table 1.

Children from GI had difficulties in keeping the letters in a straight line (failure in ascending/descending lines) and presented difficulties in terms of legibility (irregularity of dimensions and bad shapes) that may have been caused by deficits of visuo-motor integration (EH, CO), visual perception (VC), and fine motor function (FMP), as shown in Table 1. As this scale is scored considering the schoolchild's errors, GI students showed a higher average of errors when compared to GII, suggesting handwriting legibility flaws, indicating dysgraphia.

In Table 3, a correlation analysis was performed for GI, between the variables of DTVP-3 and BOT-2 with those of the Dysgraphia Scale, in order to verify what are the possible relationships between the variables of visual perception and motor proficiency in relation to the variables of the Dysgraphia Scale.

There was no relationship between the motor function variables (BOT-2) and the dysgraphic scale, suggesting that there may be a difficulty in motor programming, before starting the handwriting movement. There was a positive and moderate relationship between CF and FL, indicating that the perception of geographic form and/or letters influenced the performance in maintaining handwriting within a space, such as lines a notebook for writing; there was a moderate and negative relationship between PF, RL, and EH subtest, indicating that difficulties in performing letter forms, with less retouching or corrections, might be impacted by eye-hand coordination, suggesting that the children from GI perform letters; they needed visual feedback.

Table 3

Correlation Between DTVP-3 and BOT-2 and Dysgraphia

Variable	Statistics	EH	FC
FL	Correlation coefficient (r)	-0.260	0.447
	p-value	0.181	0.017*
RL	Correlation coefficient (r)	-0.408	0.191
	p-value	0.031*	0.329
PF	Correlation coefficient (r)	-0.617	0.139
	p-value	0.000*	0.481

Notes. FL: Floating Lines; RL: Retouched Letters; PF: Poor Forms; EH: Eye-Hand Coordination; FC: Form Constancy Spearman's Correlation Analysis (*$p < 0.05$).

Discussion

The results presented in this study indicate that children with Learning Disabilities can manifest significant visomotor impairment and fail in legibility and handwriting quality. LD children had difficulties in planning and executing fine motor precision and fine manual control, due to flaws in visual perception, such as form constancy and visual closure skills.

Visual closure refers to the ability of identify forms or objects from incomplete presentations, which enables children to quickly recognize objects, shapes, and forms, either mentally completing the image or by matching it to information previously stored in long term memory (Visser et al., 2012). As our findings pointed out, children failed in visual closure skills, and by consequence, they had difficulties in executing letters forms and traces correctly.

Regarding form constancy, this ability requires the perception that a form can be repeated in different situations and directions. This ability is directly related to the perception that a letter can be repeated within a word or be present in other words. Such perception favors not only the establishment of visuospatial concepts and programming of the motor act, but also favors the increase of reading accuracy and orthographic lexicon, which will directly interfere in the formation of long-term lexical memory. In this study, the low performance in the quality of handwriting may be related to failures in the development of visuo-motor integration, collaborating with other research findings (Crawford & Dewey, 2008; Germano, Giaconi, & Capellini, 2016; Capellini, Giaconi, & Germano, 2017).

Also, GI children had difficulties in visomotor integration skills, such as copying and eye-hand coordination skills. Therefore, with regard to the process of developing visual and motor perception skills, the children must have the addition of voluntary attention to program and reprogram movements that will enable motor activity, which could not be observed in GI children's (Halsband & Lange, 2006; Brown, Unsworth, & Lyons, 2009; Feder & Majnemer, 2007). Longcamp, Velay, Berninger, and Richards (2016) described that the overall shape of a word traced on a piece of paper implies the existence of a memory trace of a sequence of gestures necessary to produce each character (the so-called generalized motor programs). When this memory develops disorganized, the shaping of the letters becomes difficult, and poor writers might overactivate the visual system.

The results also indicated that children with LD had difficulties with precision and fine manual control. It was possible to observe that difficulties observed in fine motor integration were due to flaws in visual skills (visual closure) and motor skills (precision). Corroborating Martin et al. (2010), the development of precision is performed mainly by intrinsic and extrinsic muscles of the hand that together perform different activities that require more refined skills such as writing. That said, studies report that Fine Motor Integration becomes more effective as visual perception and movements of fingers and hands are well coordinated, making this ability an essential component for learning and refining praxis skills (Graham, Harris, & Fink, 2000; Brown & Rodger, 2008; Rosenblum, 2008; Rosenblum, Aloni, & Josman, 2010). Thus, the results of this study suggest that the difficulty of visual perception can impact the programming and use of these small hand muscles, causing possible dysgraphia.

In addition, these findings indicate that children with LD may suffer from academic activities and also from daily life activities, so common, which involve handwriting. Skjaerven, Kristoffersen, and Gard (2008) reported that the good performance of the movement reflects the interaction between learning experiences, the different levels of difficulty of the task, and the environmental factors. Furthermore, the quality of handwriting reflects how these movements are controlled and coordinated. In this way, with academic practices, the capacity to acquire new movements expands, being able to be noticed through qualitative (legibility of letters, alignment of writing) and quantitative (number of written words) changes.

Another important finding in this study refers to the quality of handwriting, based on the dysgraphic scale. The GI children had difficulties with movement precision, such as failures to execute and program movements in a straight line, indicated in the Descending and/or Ascending Lines item. They also presented a legibility deficit, presenting Irregularity of Dimension and poor letters forms, resulted from deficits in skills Eye-Hand Coordination, Copying, Visual Closure, and Visuo-Motor Integration. Thus, the children with LD in this study performed handwriting with capital letters, suggesting failures to obey spatial restrictions, due to visual perception failures, making the visuomotor automatization process unfeasible. Errors were reported in LD, like overly sharp turns, letters misaligned, broken or irregularly spaced between them (Smits-Engelsman & Van Galen, 1997; Vinter & Chartrel, 2010), corroborating with our results.

Hence, such deficits can be related to an increased vulnerability of neural work that is responsible for the sensory-motor integration of information (Smits-Engelsman, Wilson, Westenberg, & Duysensal, 2003). Therefore, in the presence of LD, praxis and gnosis functions are more likely to be altered, affecting manual dexterity and spatial and temporal organization, making it even more difficult to learn writing skills and functional tasks that require greater manual dexterity (Summers, Larkin, & Dewey, 2008; Martin et al., 2010).

The results obtained in this study agree with the findings (Shevell et al., 2005; Kim, Carlson, Curby, & Winsleret, 2016), which indicated that children with LD present a predominant delay in the acquisition of cognitive, motor, linguistic, and/or social skills, having a significant and continuous impact on the development of others academic skills. Lyon at al. (2001) also highlighted that LD have a learning deficit of an intrinsic (neurobiological) cause, but which can be aggravated by the extrinsic component (for example, environmental or instructional).

In accordance, Datchuk (2015) referred that child with LD may show persistent problems with handwriting and may need a continued support or remediate programs that focus on training visual cues or fine motor coordination. Indeed, authors (Case-Smith, 2002) have emphasized that the multidisciplinary intervention with children who have fine motor and visual perception difficulties may contributes to the improvement of their skills, i.e., handwriting.

Conclusion

It was possible to conclude that children with learning disabilities presented difficulties in the visual closure and form constancy skills, causing difficulties in fine motor function and legibility of handwriting. Such difficulties can be justified by deficits intrinsic to their condition, such as the failure to form long-term memory of visual information and the establishment of sensorimotor maps.

As a consequence, these failures cause difficulties to perform not only tasks related to school, but also, daily life activities. The need for multidisciplinary interventions with different trained professionals (occupational therapists, speech therapists, pedagogues, among others) that can contribute to the overall improvement of these children with Learning Disabilities is highlighted, aiming to curricular adaptations for these children in the classroom, and also preparing them for the accomplishment of a full life in the future.

Disclosure Statement

No potential conflict of interest was reported by the author(s).

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