Chapter

Visual-Motor Perception and Handwriting Performance of Students with Mixed Subtype Dyslexia

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Abstract

This study aimed to characterize and compare the visual-motor perception and handwriting performance of students with mixed dyslexia and students with good academic performance. Twenty-six schoolchildren of both sexes participated in this study, aged 9 to 11 years and 11 months old, from fourth and fifth grades of an elementary school in municipal public schools, from an average socioeconomic level, divided into two groups: Group I (GI) composed of 13 students with a multidisciplinary diagnosis of mixed developmental dyslexia and Group II (GII) composed of 13 students with good academic performance from a municipal school and matched according to gender, education, and age to GI. All students in this study were subjected to the application of the following procedures: Developmental Test of Visual Perception III—DTVP-III, Dysgraphia Scale and writing analysis by NeuroScript MovAlyzeR 6.1 software. The results were analyzed statistically using the following tests: Mann-Whitney test, Wilcoxon signed-rank test, and Friedman test, aiming to verify intragroup and intergroup differences for the variables of interest in the DTVP-III, the Dysgraphia Scale, and the measures of handwriting speed and pressure by the MovAlyzeR software. The results were analyzed statistically at a significance level of 5% (0.050). The results showed that there were statistically significant differences between GI and GII in the parameters of the Dysgraphia Scale, floating lines, irregular spaces between words, junction points, sudden movements, and dimension irregularities. GII showed a superior performance in relation to GI in the variables analyzed with the DTVP-III in visual-motor integration, reduced motricity perception, and general visual perception. There was no statistically significant difference between GI and GII in the variables analyzed by the MovAlyzeR software. The results of this study allowed us to conclude that students with mixed dyslexia present a lower performance profile than the students with good academic performance in general visual perception, reduced motricity visual perception, and visual-motor perception skills, which may be the cause of the quality of dysgraphic writing characterized by floating lines, irregular spaces, junction points, sudden movements, and dimension irregularities.

Keywords: dyslexia, evaluation, handwriting, visual motor perception skills

1. Introduction

According to Reid [1], dyslexia refers to differences in individual processing, in which they are characterized by difficulties in the beginning of literacy, affecting the acquisition of reading, writing, and spelling. In addition, there are failures in cognitive, phonological and/or visual and memory processes, information retrieval, speed processing, time management, coordination, and automation [2].

Developmental dyslexia, according to Galaburda and Cestnick [3], is presented as a condition that manifests near the age of 3, in which the child demonstrates a delay in verbal development. For the author, dyslexia is considered to be phonological and occurs due to damage in the region of the upper temporal gyrus and temporo-parietal regions, while visual dyslexia is associated with parieto-occipital regions.

Dyslexia can manifest itself through three subtypes, in which the phonological subtype is due to a dysfunction in the region of the upper temporal gyrus and the temporo-parietal regions, thus causing changes in auditory processing. Some authors indicate that the decrease in the auditory information processing capacity may be the basis of the problems manifested in this subtype [4].

Regarding prevalence, there is a variation of 6–17% of the school-age population [5]. In addition, dyslexia has a high probability of hereditary issues, in which the chances of being predominant in males are two to three times higher [6, 7]. They may also present deficits in fine motor skills, which cause changes in letter and spelling in copy tasks [8], difficulty in bimanual coordination, and manual dexterity that would justify the occurrence of dysgraphia in this population [9].

For there to be precision in the form of letters, it is necessary to use fine motor skills, visual perception, visuo-motor integration, maturity, and integration of cognition [10], making the development of writing a demanding process, long and complex [11]. The acquisition of handwriting requires that there is a combination of coordination of visuo-motor skills with motor, cognitive, and perceptual skills, being tactile-kinesthetic, organization in space, and time [11].

Mathes and Denton [12] also mentioned that there is a combination of biological and environmental phenomena in learning to write in which they involve motor, sensory-perceptual, and socio-emotional integrity. Schirmer et al. [13] described that the acquisition of written language, as well as oral language, involves several brain regions, among them the parieto-occipital area, in which there is the primary visual cortex, the main responsible for the processing of graphic symbols and areas of the parietal lobe that are responsible for visual–spatial issues of the spelling, information that is recognized and decoded in the Werneck area, in which it is responsible for the understanding of the language and for the written expression it is necessary to activate the primary motor cortex and Broca's area.

Thus, in order to make use of handwriting, representations are needed to assist the visual memory of each letter, the recognition of the features that make up each letter and the ability to reproduce features in a motorized way while respecting order and direction [14]. Visual perception is a system that is concerned with the identity of the object, as well as with the location in space, where it is directly linked with action systems [15]. Changes related to fine motor function can cause failures in the development of writing skills [16]. These changes affect the student's performance, influencing the quality and quantity of learning in the classroom, also relating the student's motivation and self-esteem. With this, the cause of changes in fine motor coordination is noticeable, which is mainly responsible for the writing layout (graphics/calligraphy) since it is one of the skills learned with more difficulty.

Those manifestations might be related with dysgraphia. Dysgraphia is referred to as a difficulty in written expression, in which the individual can present an appropriate intellectual novel and receive appropriate instructions for the acquisition of handwriting during the literacy process. When submitted to the practice of writing during his academic training and, even so, he has the inability to produce an understandable and acceptable writing, it is called as dysgraphia [17].

In Brazil, there is a scarcity of procedures for evaluating handwriting; those that exist are available only for research purposes, in which, it is impossible for the education and health professional to use them, such as the Dysgraphic Scale [18]. Although there are international studies investigating the perception-visual-motor relationship, reading and writing in the population of students with dyslexia [16, 19], these studies are restricted in Brazil, thus making it difficult to establish the perception visual-motor profile of this population.

The need to investigate and understand the perceptual-visual-motor performance of these students with dyslexia is linked to the fact that many of the handwriting errors are identified as spelling errors in which they may actually be covering up errors of calligraphic nature, such as the poor shape of letter in which it triggers unintelligible handwriting [19].

Thus, the aim of this chapter was to characterize and compare the visual-motor perception and handwriting performance of students with mixed subtype dyslexia and students with good academic performance.

2. Method

This project was approved by the Research Ethics Committee of the Faculty of Philosophy and Sciences of the São Paulo State University "Júlio de Mesquita Filho" (UNESP), Marília, São Paulo, Brazil, under the protocol number 3.098.493.

Twenty-six students, of both sexes, participated in this study, aged 9 years to 11 years and 11 months, from the fourth and fifth grade levels of an elementary school, with average socioeconomic level, divided into two groups: Group I (GI): composed of 13 students with a multidisciplinary diagnosis of developmental dyslexia of the mixed subtype; and Group II (GII): composed of 13 students with good academic performance, paired according to sex, education, and age group with GI.

The GI students were assessed by an interdisciplinary team from Investigation Learning Disabilities Laboratory, Department of Speech and Hearing Sciences, São Paulo State University "Júlio de Mesquita Filho" (UNESP), Marilia, São Paulo, Brazil, following criteria [20, 21]. As inclusion criteria, the presentation of the Free and Informed Consent Term signed by the parents or guardians was considered and they were not submitted to any speech therapy, pedagogical or psychopedagogical intervention. Failure to meet at least one of the criteria described above would automatically exclude students from the sample in this study. The GII students in this study were selected at a public school indicated by their teachers for having good academic performance in Portuguese and Mathematics. From this indication, students were submitted to the application of the School Performance Test—TDE [22]. Only schoolchildren who achieved average to superior performance were included in the GII of this study. The exclusion criterion for GII was the presence of sensory deficits (hearing and/or visual impairment), cognitive or physical, according to aspects described in the school record. Excluded from this study were students who had already undergone some type of speech therapy remediation or who did not write in cursive.

The students were evaluated individually and submitted to the procedures:

- *Dysgraphic Scale* [18]: students were asked to write a dictation using a 2B pencil and sheet without lines and guidelines. Capitalized writing was performed, as the GI students were unable to execute the cursive letter. The evaluated items were floating lines; descending and/or ascending Lines; retouched letters; irregularity of dimension; poor forms; 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* [2]: the procedure is validated for students aged 4 years to 12 years and 11 months. The protocol consists of a battery of five subtests being eye-hand coordination (EH), coping (C), figure-ground (FG), visual closure (VC), and form constancy (FC). The composite score generated allows the classification in relation to the general visual perception (GVP, composed by the somatory of all subtests), motor-reduced visual perception (MRVP, composed by the subtests figure-ground, visual closure and form constancy), and visual-motor integration (VMI, composed by the subtests coping and eye-hand coordination). The students were classified according to the composite scores. The students 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).

- *Analysis of writing by* the *NeuroScript* MovAlyzeR *Software*: the writing analysis procedure was performed by a software that analyzes the movement performed through a graphics tablet, which is used to interpret the movements generated by a pen, providing data of inclination, speed, acceleration, and pressure of the pen. In addition, it is used to process handwritten images, being able to record and segment the writing, descent, elevation, and pauses of the pen.

The data obtained were analyzed statistically in order to compare the intragroup and intergroup results. The IBM SPSS Statistics program (Statistical Package for the Social Sciences), version 25.0, was used to obtain and analyze the results.

The results were analyzed statistically using the following tests, the Mann-Whitney test, Wilconxon signaled test, and the Friedman test, aiming to verify the intragroup and intergroup differences studied for the variables of interest in DTVP III, the Dysgraphic Scale, and the analysis of the speed and pressure measures of writing by the MovAlyzeR software aiming to characterize and compare the performance between the groups. The results were analyzed statistically at a significance level of 5% (0.050). The level of significance (p-value) is marked with an asterisk. Descriptive analysis of the data was performed by obtaining the values of mean, standard deviation, and p-value.

3. Results

With the application of the Mann-Whitney test, it was possible to observe that there was a statistically significant difference in the comparison between GI and GII in floating lines, irregular space, junction point, sudden movements, and dimension irregularity, demonstrating that the group of students with good performance academic (GII) had a lower score in the cited parameters when compared with the group of students with mixed dyslexia GI (**Table 1**).

In the qualitative analysis of the Dysgraphic Scale, it was possible to observe that 100% of the students of GI presented quality of dysgraphic writing, whereas, 100% of the students of GII did not present quality of dysgraphic writing.

Table 2 shows the mean value, standard deviation, and p-value of the comparison between GI and GII in the gross score subtests of DTVP-3.

Parameters	Group	Mean	Standard deviation	p-Value
Floating lines	I	1.38	0.51	0.002*
	II	0.62	0.51	
	Total	1	0.63	
Descending and/or ascending lines	I	0.77	0.26	0.144
	II	0.58	0.34	
	Total	0.67	0.31	
Irregular space	I	0.85	0.24	0.002*
	II	0.39	0.36	
	Total	0.62	0.38	
Retouched letters	I	1.23	0.73	0.294
	II	0.92	0.76	
	Total	1.08	0.74	
M, N, U, and V curvatures and angulations	I	0.08	0.19	>0.999
	II	0.08	0.19	
	Total	0.08	0.18	
Junction points	I	1	0.58	0.001*
	II	0.15	0.38	
	Total	0.58	0.64	
Collisions and grips	I	2.04	0.8	0.268
	II	1.5	1.22	
	Total	1.77	1.05	
Sudden movements	I	1.23	0.73	0.002*
	II	0.31	0.48	
	Total	0.77	0.77	
Dimension irregularity	I	1.39	0.65	0.006*
	II	0.58	0.64	
	Total	0.98	0.75	
Poor shape	I	0.92	0.19	0.076
	II	0.69	0.38	
	Total	0.81	0.32	
Total	I	10.89	1.71	<0.001*
	II	5.81	1.56	
	Total	8.35	3.05	

**(p-value < 0.05).*

Table 1.
Distribution of mean values, standard deviation, and p-value when comparing GI and GII performance.

Referring to **Table 2**, it was possible to analyze that all subtests showed a statistically significant difference. According to the visual-motor coordination subtest, GII showed a superior performance in relation to GI. In the copy subtest, it is possible to observe that GII performed better than GI. In the figure-ground subtest, it is possible to observe that GII performed better than GI. In the visual closure subtest, it is possible to observe that GII showed a superior performance in relation to GI. In Form constancy subtest, it is possible to observe that GII performed better than GI.

Subtests	Group	Mean	Standard deviation	p-Value
VMC	I	140.31	24.2	
	II	181.69	7.17	<0.001*
	Total	161	27.41	
CO	I	27.54	5.36	
	II	41.46	6.96	<0.001*
	Total	34.5	9.35	
FG	I	49.23	8.31	<0.001*
	II	59.54	3.41	
	Total	54.38	8.14	
VC	I	11.08	3.59	<0.001*
	II	17.62	3.12	
	Total	14.35	4.69	
FC	I	38.62	7.48	0.001*
	II	47.62	2.53	
	Total	43.12	7.14	

Caption: VMC—visual-motor coordination; CO—copy; FG—figure-ground; VC—visual closure; and FC—form constancy.

Table 2.
Distribution of mean, standard deviation, and p-value for GI and GII in the gross score subtest.

Table 3 shows the mean value, standard deviation, and p-value of the comparison between GI and GII in the subtest Description of Terms.

Referring to **Table 3**, the subtests visual-motor coordination, visual closure, and constancy of form did not present a statistically significant difference. In the subtest visual-motor coordination, it is possible to observe that GII presented a superior performance in relation to GI. In the copy subtest, it is possible to observe that GII performed better than GI. In the figure-ground subtest, it is possible to observe that GII performed better than GI. In the visual closure subtest, it is possible to observe that both groups showed similar performance. In the form constancy subtest, it is possible to observe that GII presented a superior performance in relation to GI. **Table 4** shows the mean value, standard deviation, and p-value of the comparison between GI and GII in the somatory of terms.

According to **Table 4**, all subtests showed a statistically significant difference. It is possible to observe that in the visual-motor integration subtest, GII presented a superior performance in relation to GI. In the Motor-Reduced Visual Perception subtest, GII showed a superior performance in relation to GI, as well as in the general visual perception subtest, in which GII also presented superior performance in relation to GI. **Table 5** shows the mean value, standard deviation, and p-value of the comparison between GI and GII in the subtest description of terms.

According to **Table 5**, all subtests showed a statistically significant difference. It is possible to observe that in the visual-motor integration subtest, GII presented a superior performance in relation to GI. In the reduced visual perception to the motor subtest, GII showed a superior performance in relation to GI, as well as, in the general visual perception subtest, in which GII presented superior performance.

In this analysis, the Wilcoxon Signed Posts Test was applied in order to verify possible differences between the subtests in the groups.

Subtests	Group	Mean	Standard deviation	p-Value
VMC	I	4	0	0.149
	II	4.31	0.75	
	Total	4.15	0.54	
CO	I	4	0	<0.001*
	II	6	1.35	
	Total	5	1.39	
FG	I	4	0	0.033*
	II	4.54	0.88	
	Total	4.27	0.67	
VC	I	3.92	0.28	>0.999
	II	3.92	0.28	
	Total	3.92	0.27	
FC	I	4.08	0.28	0.056
	II	4.62	0.87	
	Total	4.35	0.69	

Caption: VMC—visual-motor coordination; CO—copy; FG—figure-ground; VC—visual closure; and FC—form constancy.

Table 3.
Distribution of mean values, standard deviation, and p-value of GI and GII in the subtest description of terms.

Subtests	Group	Mean	Standard deviation	p-Value
VMI	I	50.62	3.95	0.002*
	II	80.85	21.61	
	Total	65.73	21.66	
MRVP	I	50.54	6.39	<0.001*
	II	78.77	16.17	
	Total	64.65	18.77	
GVP	I	48.08	8.98	<0.001*
	II	82.77	14.46	
	Total	65.42	21.26	

Caption: VMI: visual-motor integration; MRVP: motor-reduced visual perception; and GVP: general visual perception.

Table 4.
Distribution of mean values, standard deviation, and p-value of GI and GII in the visual motor integration subtest.

Table 6 shows the mean, standard deviation, and p-value for the speed and pressure subtests in Attempts 1 and 2 of GI.

According to **Table 6**, it is possible to observe that there was no statistically significant difference. In the speed subtest, Attempt 1 and Attempt 2 had similar average values. In the pressure subtest, it is possible to observe that in Attempt 1, there was a higher average in relation to Attempt 2. **Table 7** shows the values of mean, standard deviation, and p-value for the speed and pressure subtests in trials 1 and 2 of GII.

Subtests	Group	Mean	Standard deviation	p-Value
VMI	I	4	0	<0.001*
	II	5.46	1.13	
	Total	4.73	1.08	
MRVP	I	4	0	<0.001*
	II	5.08	1.04	
	Total	4.54	0.91	
GVP	I	4	0	<0.001*
	II	5.23	1.01	
	Total	4.62	0.94	

Caption: VMI: visual-motor integration; MRVP: motor-reduced visual perception; and GVP: general visual perception.

Table 5.
Distribution of mean, standard deviation, and p-value for GI and GII in the subtest description of terms.

Subtests	Mean	Standard deviation	p-Value
T1-Speed	0.74	0.39	0.6
T2-Speed	0.75	0.38	
T1-PRE	79.17	41.06	0.463
T2-PRE	77.32	40.59	

Caption: Speed; PRE: Pression T1—Attempt 1, T2—Attempt 2.

Table 6.
Distribution of mean values, standard deviation, and p-value in the GI subtests.

Subtests	Mean	Standard deviation	p-Value
T1-Speed	0.74	0.31	0.753
T2- Speed	0.68	0.23	
T1-PRE	102.19	34.87	0.695
T2-PRE	95.73	29.98	

Caption: Speed; PRE: Pression T1—Attempt 1, T2—Attempt 2.

Table 7.
Distribution of mean values, standard deviation, and p-value in attempts at GII.

According to **Table 7**, it is possible to observe that there was no statistically significant difference. In the speed subtest, Attempt 1 had a higher average than Attempt 2. In order to verify a possible difference between both groups in the subtests of interest, the Mann-Whitney test was applied.

4. Discussion

Based on the data obtained, it was observed that all students with mixed dyslexia (GI) presented the quality of dysgraphia writing in relation to the group with good academic performance (GII) regarding the Dysgraphia Scale procedure [18].

In the variables of DTVP III, visual-motor coordination, copy, background figure, form constancy, and visual closure, GI presented a lower performance in relation to GII, as well as in the variables of visual motor integration, reduced visual perception to the motor and general visual perception. In the analysis of the NeuroScript MovAlyzeR Software, there was no statistically significant difference between the groups studied.

According to the literature, the presence of dysgraphia in students with dyslexia suggests the existence of changes in the tracing of letters in tasks involving copying, and manual dexterity [23].

Studies have shown that students with dyslexia present changes in motor skills, involving difficulty in bimanual coordination, manual dexterity, and fine motor skills, justifying the occurrence of dysgraphia [9, 24, 25].

Regarding the variables studied in the Dysgraphia Scale [18], students with mixed dyslexia presented an inferior performance in floating lines, irregular space, junction point, sudden movements, and dimension irregularity. Students with dyslexia had a predominant score in retouched letters and junction points, considering that they were due to changes in the skills of discrimination, memory, visuo-spatial relationship, and form constancy.

Concerning the perceptual-visual-motor function, according to Brow and Rodger [26], there is a combination of the visual-motor, motor, cognitive, perception-visual skills (eye-hand coordination) position in space, spatial relationship, figure-ground, and form constancy. Therefore, students with dyslexia are prone to show manifestations of visual perception changes due to dysfunctions in the brain areas responsible for visual-spatial perception, which is responsible at the time of writing [19].

In this study, it was proven that students with dyslexia showed changes indicating deficits in visual-motor perception, in addition to presenting an inferior performance in visual-motor coordination skills, position in space, copy, visual closure, visual motor speed, and constancy in a way when compared to the group with good academic performance.

Visual-motor perception skills are related to handwriting, that is, graph-motor actions and also reading skills. These skills depend on the recognition of details, visual-spatial organization, and spatial relationship between integration figures of the parts of a whole, assigning meaning to the shapes of the letters and thus affecting the graph-motor performance [27–29].

Thus, it is considered that the difficulty in performing the skills of visual-motor perception and visual perception in these students compromise the performance of handwriting, and dysgraphia may occur as described in the literature [28].

There are technologies that assist in writing and analyzing handwriting, aiming to estimate parameters for movements performed in the motor act of writing. A study of Costa [30] analyzed through the Neuro Script MovAlyzeR software the number of segments, reaction time, and pressure of students and preschoolers. With regard to pressure, preschoolers showed less pressure when compared to students, also registering lower values in the pressure of the pencil grip. The study of Barrientos [31] states that the pressure exerted at the time of writing has a progressive increase according to age in the copy tasks in students with learning difficulties, and students without learning difficulties tend to have less pressure at the moment of writing.

The fact that there was no statistically significant difference between the variables studied (speed and pressure) in the comparison between the groups of this study raises some hypotheses such as the size of the studied sample of students with mixed dyslexia, requiring the continuation of the study, due to the fact that be a study limitation or the lack of handwriting practices in the academic grade of elementary school in our country, making different profiles of students with or without specific learning disorders do not differ in terms of the parameters analyzed.

The hypothesis of this study was partially confirmed since the measures of visual-motor perception and quality of writing were fundamental for the differentiation of handwriting in students with mixed dyslexia and with good academic performance; however, the analysis of writing by the software used in this study did not allow stem differentiation.

The establishment of the handwriting profile of students with mixed dyslexia is extremely important for the discussion of the subtype, especially for the investigation of whether it has a perceptual-visual-motor profile and different writing quality than students with good school performance, thus allowing to characterize this population both for the performance of the differential diagnosis and for the performance of interventions in the clinical and educational context, taking into account the fact that Speech Language Pathology is the area that investigates the changes in information processing and, consequently, its impact on the acquisition and in the development of reading and writing and can help the teacher's understanding of handwriting alteration.

The teachers' lack of knowledge about the perceptual-visual-motor performance of students with mixed dyslexia causes confusion about the nature of the writing error, causing spelling errors to be confused with handwriting errors, for example, the poorly drawn letters that cause the writing of an unintelligible letter or word. Thus, it is necessary to use perceptual-visual-motor assessment procedures, so that educational intervention programs are designed in order to reduce the impact of poorly written letters on the spelling of students with dyslexia, more specifically students with mixed dyslexia.

5. Conclusion

The results of this study allowed us to conclude that the students with mixed dyslexia in this study presented an inferior performance compared to the students with good academic performance in relation to the skills of visual-motor coordination copy, figure-background, visual closure, and constancy of form, characterized by changes in general visual perception, visual perception of reduced motricity, and visual-motor perception.

In the intragroup analysis of the GI, it was observed that the students with mixed dyslexia had a similar visual-motor perception performance between them, showing a statistically significant difference only in the subtests gross score and scalar score. In the GII, students with good academic performance showed a superior performance in most of the subtests studied, with a statistically significant difference in gross score, percentile of rank, scalar score, description of terms, visual-motor integration, reduced visual perception to motor, perception general visual, and scalar score. From the intergroup analysis, GII showed a superior performance in all studied subtests.

In the Dysgraphia Scale, it was possible to observe that all of the group of students with mixed dyslexia presented writing considered dysgraphic characterized by floating lines, irregular space, junction point, sudden movement, and irregularity of dimension.

With regard to the analysis of writing using the MovAlyzeR software, it was possible to verify that this instrument did not allow the differentiation between the groups of this study in the variables of speed and pressure.

At the end of this study, we concluded that it was possible to characterize and compare two different populations of students and, in addition, to observe the aspects that make them distinct from the evaluation of handwriting. It is clear that there is still a lack of studies that identify, along with other procedures, what characteristics students with difficulty regarding proficiency in handwriting present, specifically students with the diagnosis of dyslexia and its subtypes.

Thus, future studies should be carried out with an aim of investigating whether the characteristics evidenced in this study may or may not be associated with changes in the final motor function, because only then it will be possible to plan appropriate guidelines and strategies for the students diagnosed with mixed dyslexia to overcome their handwriting difficulties.

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