Characterization of gaze in handwriting of High and Low Frequency Word of Schoolchildren with Dyslexia

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Abstract

Writing is extremely important for our academic and professional life and can affect our performance in productive educational activities, favouring us or not. Schoolchildren with dyslexia bring difficulties and reduced school performance due to their condition of deprivation in written production. This is because schoolchildren with dyslexia have difficulty acquiring spelling knowledge and show poor phonological skills. This study aimed to characterize the performance of schoolchildren with dyslexia in "gaze" for the handwriting of High and Low-frequency words. A total of 24 schoolchildren participated in the study. They were between 8 to 11 years and 11 months of age, of both sexes, and they were attending the 3rd to the 5th year of Elementary School in the city of Marília-SP. The schoolchildren were divided into groups: GI, composed of 12 schoolchildren with an interdisciplinary diagnosis of developmental dyslexia, and GII, composed of 12 schoolchildren with good academic performance, paired with GI according to the school grade level. These schoolchildren were submitted to computerized handwriting evaluation using a Brazilian adaptation of the Software Ductus. All schoolchildren were submitted to a copy of words already selected according to Brazilian Portuguese criteria of frequency and codification rule. A measure of "gaze" was used, that is, when the schoolchildren stopped their handwriting to search/look up at the screen to confirm the information about the words. The results indicated a significant difference between GI and GII, with GI schoolchildren performing more gaze when compared with GII, i.e., taking longer motor breaks to perform the gaze. Therefore, there was a rupture in the central processing with the peripheral when the child performed the gauze more times since he had to confirm the characteristics of this word during the writing process (difficulty in accessing the orthographic lexicon) and with that, there was a break in the movement of handwriting (since there was not enough information in the central plane to

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complete that motor memory and finish the word). It was concluded that there were gaps between the central (orthographic) and peripheral (motor pauses processes, suggesting deficits in the formation of motor programs for GI and the lack of automation of motor processes.

Key words: Students with Dyslexia; Gaze track; Handwriting

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1. Introduction

The handwriting process can be understood as something broader, as it requires several cognitive and motor processes, called central processes (orthographic modules) and peripheral (motor modules). (Kandel & Perret, 2015). The first stage is at the central processing level, which is responsible for activating our spelling knowledge about the desired word, recalling the correct sequence of letters to form the word and the order of each letter for that word. Central processing will be present throughout the writing process, modulating motor production, that is, correcting this process and updating it. The next process is peripheral processing, which is the process responsible for the motor production of writing. Motor production does not depend only on the format of the letters that must be written but also on the orthographic representation of each letter when we remember them to write (Kandel & Perret, 2015).

As mentioned by Purcell et al. (2011), spelling-specific central processes are usually identified as orthographic long-term memory (the orthographic lexicon); phoneme-grapheme conversion, and orthographic working memory (the graphemic buffer). The authors also report that there is an interaction within the central processes, namely between the orthographic working and long-term memories and between the long-term orthographic memory and the phoneme-grapheme conversion. The motor aspects of letter production are modulated by peripheral processes that regulate movement execution (Van Galen, 1991).

It is essential to emphasize that these processes take place in a cascade form, that is, there is a hierarchy of processing (it will always start with the central processing and then move on to the peripheral processing) and, because it is a cascade, the central will always be present in motor production (in peripheral action), since the modulation of the central in the peripheral will always be

present. This fact brings to light the integration of both processes (central and peripheral) in handwriting, so if there is any intercurrence in the central, it will affect the peripheral. (Kandel & Perret, 2015).

Thus, studies indicate that the type of stimulus (words) can interfere with the execution of the writing movement, in legibility and speed measures (Roux, Mckeeff, Grosjacques, Afonso & Kandel, 2013). Studies have shown an interaction between these processes, and investigations have focused on analyzing the interference of orthographic aspects in handwriting (Kandel & Perret, 2015a; Roux et al., 2013). The production of movement can suffer from the influence of variables that regulate the orthographic process, such as frequency and lexicality (Roux et al., 2013). These interactions have already been demonstrated in languages with spellings with more excellent opacity, such as French and English (Kandel & Perret, 2015a; 2015b; Sumner, Connelly, & Barnett, 2013; 2014) and those with greater transparency, such as Spanish (Afonso & Álvarez, 2019; Afonso, Álvarez, & Kandel, 2015; Afonso, Suárez-Coalla, González-Martín, & Cuetos, 2018), but not for the Brazilian Portuguese language.

The Brazilian Portuguese writing system has a bidirectionality principle, characterized by the rules of grapheme-phoneme decoding for reading and the rules of phoneme-grapheme coding for writing. Thus, the system for Brazilian Portuguese can be characterized by orthographic transparency (with the occurrence of common words and words that are written considering contextual rules) and orthographic opacity (with the occurrence of irregular words). To be able to write a word, the child needs to understand that the writing system comprises three types of relationships between the phonemes and graphemes of the alphabet, according to Scliar-Cabral (2003a).

Thus, in searching for more precise measurements, recent studies point to digitizing tables and software to capture more precise measurements (Germano & Capellini, 2019; Kandel & Perret, 2015).

However, Brazilian studies are scarce and restricted. As central and peripheral processes interact during handwriting, it is possible to verify this interaction by measures such as “gaze” or lifting the gaze, using specific software (Kandel & Perret, 2015).

The gaze is understood as the moment when the student stops his/her writing and looks up towards the blackboard or computer to check writing information, such as spelling and/or tracing aspects. So, it can be seen as a “break” in the central processing with the peripheral processing since characteristics of a specific word had to be confirmed during the handwriting process. (Kandel &Valdois, 2006; Lallier et al., 2014).

Behavioural measures, such as gaze, are justified because a gaze lift implies that the child could not obtain information on the spelling of the first or second

syllable before movement initiation, indicating that spelling information available in memory is insufficient. (Kandel &Valdois, 2006)

Studies showed that dyslexic individuals have a lower performance in spontaneous handwriting when compared to schoolchildren with good performance and that people with dyslexia produced fewer readable words and a more significant number of unreadable words within one minute (Bosga-Stork et al., 2015). According to Reid (2016), developmental dyslexia is characterized by differences in individual processing, often characterized by difficulties presented at the beginning of literacy, compromising the acquisition of reading, handwriting and spelling. Such impairments may be due to failures in cognitive, phonological and/or visual processes.

Therefore, this study is justified by the paucity of studies characterizing the gaze of schoolchildren with dyslexia during handwriting production based on the use of software in the Brazilian context.

In this way, this study aimed to characterize the performance of schoolchildren with dyslexia in "gaze" (gaze lifting) for the handwriting of high and low-frequency words using Ductus software.

2. Material and Method

Research submitted and approved by the Research Ethics Committee (CAAE number 58724716.3.0000.5406). All participants presented the free and informed consent form. Twenty-four schoolchildren participated, divided into GI (12 schoolchildren with an interdisciplinary diagnosis of developmental dyslexia), GII (12 schoolchildren with good academic performance, matched with GI according to the school year and sex), age group between 8 and 10 years and 11 months of age, from the 3rd to the 5th year of Elementary School. Group II was paired with Group GI, composed of 10 children with good academic performance in relation to chronological age. The children of GII were indicated by their teachers with above average performance in school assessments of Portuguese in at least two consecutive bimesters and without any indication of learning problems. Their general cognitive abilities assessed at school were within the normal range, according to school records. According to school records, schoolchildren with sensory, motor, or cognitive disabilities were excluded. The diagnostic criteria adopted were described in the literature (American Psychiatric Association, 2014).

All students in this study underwent a writing assessment using the Brazilian adaptation of the computerized writing assessment software Ductus (Ductus ® software; Guinet & Kandel, 2010). A laptop computer (adapted version;

Germano, 2018; Germano & Capellini, 2019) and a digitizing table (Intuos Pro Wacom Pen and Touch Tablet) were used for the procedures described below.

The stimuli were presented in the centre of the notebook screen (written in capital letters - Times New Roman size 18). An auditory signal and a fixation point (100 ms) preceded the presentation of the stimuli. The stimulus remained on the screen until the child had finished writing the word. Children were instructed to write the word on the graphics tablet as soon as it appeared on the notebook screen. Thirty high-frequency words were selected. For lexical frequency manipulation, words with a frequency greater than 91 occurrences within a corpus of 2,646 words were selected according to the values provided by Germano (2018). For the lexical frequency manipulation, words were selected with a frequency above 91 occurrences within a corpus of 2.646 words according to the values provided by Germano (2018). The words were taken from school vocabulary, composed of words extracted from Portuguese Language books from the 1st to the 5th grade level of Elementary Education in the State of São Paulo (Germano, 2018). Only disyllable nouns of different syllabic complexities and regular and irregular words were included. Words were excluded written in other languages, adverbs, adverbial phrases, prepositive phrases, adjectives, months of the year, numerals, augmentative or diminutive words, slang and words composed by juxtaposition words that present some diacritical signs and words with “ç”. The list formed had words of different syllabic complexities, regular and irregular words, randomized by frequency. According to the classification of the writing coding rule of Scliar-Cabral (2003a, 2003b), for high-frequency words, ten words were classified as rule C1 (Conversion of phonemes to graphemes regardless of context - Phonographic conversion is not determined by position or phonetic context, that is, there is no restriction on the grapheme assignment in twelve phonemes); 10 words were classified as rule C2 (Conversion of phonemes to graphemes depending on position and/or phonetic context - Phonographic conversion, in these rules, depends on how the phonemes are pronounced, for the choice of letters or graphemes that will represent them) and ten words as rule C3 (Competitive alternatives – there is competitiveness for the same phonetic context, it is necessary to have a metalinguistic knowledge, especially semantics and morphology, which can help in choosing the letter or grapheme that will represent it; words are dependent on orthographic lexical memory).

A measure of "gaze" was used, that is, the moment when the child stops their handwriting to search/ looks up at the screen to confirm the information about the words. This variable represents a mark of each event by pressing the space key on the notebook keyboard for each moment in which the student raised his gaze to the screen to confirm and/or verify word information (Guinet & Kandel,

2010). As a procedure, the students wrote ten words per session, thus avoiding memory overload and fatigue.

The "Gaze" or Gaze variable was measured by pressing the space key on the keyboard each time the student looked up at the screen to confirm and/or verify word information. In order to avoid loss and/or excess marking, the application of the procedure was filmed, for the exclusive use of observation by looking up towards the notebook screen

3. Results

The results were analyzed statistically. For comparison of the two independent groups, Mann-Whitney Test was applied. The Mann-Whitney test was applied in order to verify possible differences between both groups studied, for the variables of interest considering a significance level of p-values considered statistically significant in relation to the adopted significance level (0.05), indicated by an asterisk (*). Only significant results were presented in the tables of this study.

Table 1 - Mean ranked and p-value of comparison of high and low frequency words in relation to gaze

Words (portuguese/english) high frequency words	groups	Mean ranked	P-value	Words (portuguese/english low frequency words	Mean ranked	P-value
Velha/ Old (Rule C1)	GI	15	**0,014 ***	Dama/ lady (Rule C1)	14,5	**0,032 ***
	GII	10			10,5	
Dono/ Owner (Rule C1)	GI	14,5	**0,032 ***	Regra/ rule (Rule C2)	14,5	**0,033 ***
	GII	10,5			10,5	
Porta/ door (Rule C3)	GI	14,5	**0,033 ***			
	GII	10,5				

Table 1 indicates the significant difference in the comparison between the groups for the words of high and low frequency, and the "raising the gaze" is found on the syllabic border, that is, in the passage from one syllable to the other, indicating that there is a failure of interaction between the central

(orthographic modules) and peripheral (motor modules) processes of writing production.

4. Discussion

The spelling and frequency of words influence the search for information, that is, the look, evidencing the non-formation of long-term orthographic memory for high and low-frequency words (Germano, & Capellini, 2019; Kandel & Perret, 2015; Sumner, Connelly & Barnett, 2013), as found in the comparison between the groups.

The dyslexic students in this study had difficulties with words with phoneme conversion to graphemes regardless of context (old, owner), high and low frequency, suggesting phonological difficulties. They also had difficulties in the use of words that depend on position and/or phonetic context (as in "dama") and unpredictable rules (as in "door"), which depend on lexicon formation and retrieval in long-term memory spelling.In this way, in this research, dyslexia can be related to the phonological and orthographic deficit that prevents the formation and access to the orthographic word lexicon (Germano, & Capellini, 2019; Kandel & Perret, 2015; Lallier et al., 2014, Sumner, Connelly & Barnett, 2013).

In relation to the phonological aspect, this aspect means that a letter can represent several phonemes, depending on the letters found before or after it in some words. Likewise, regarding a lexical aspect, some words do not have the same number of graphemes and phonemes (such as "velha"); thus, it is not possible to associate phonological knowledge with writing directly (Lallier et al., 2014).

Also, visual memory is essential in spelling development (Jeffries & Everatt, 2004). As several authors explain, this is the lexical writing process, in which the semantic-lexical route releases the correct sequence of letters for writing the word, either spontaneously or under dictation, by activating the graphemic output lexicon (Frith, 1985; Kandel & Perret, 2015).

Handwriting words involves analyzing incoming sensory information (visual or auditory), accessing the orthographic representation of the word to be written (either directly or through sublexical processing), and temporarily storing it in the graphemic buffer. These central stage processes are followed by allographic processes, i.e., the specification of the format in which the series of letters will be produced, including the idiosyncratic way in which each individual produces graphic characters, and this involves neuromuscular programming and execution of appropriate sequences motor skills (Van Galen, 1991).

Corroborating these findings, Kandel and Valdois (2006) evaluated schoolchildren from 1st to 5th grade in the production of words and pseudowords using the Ductus software. More recently, Bosse, Kandel, Prado, and Valdois (2014) investigated children in grades 3 and 5 by measuring the number of gaze lifts during copying. Results indicated that the number of letters processed per gaze lift during a copying task depends on reading skills (grapheme-to-phoneme relation knowledge or whole-word knowledge)

Results indicated that the schoolchildren programmed the first syllable before starting to write. The programming of the second syllable of the word would be online, evidenced by the increase in the production time of the second syllable. These differences in duration between the productions of the first and second syllables can be explained by the anticipatory conception of writing production proposed by Van Galen (1991).

In other words, as pointed out by Kandel and Valdois (2006), to write a two-syllable word, a spike in time in the production of the syllable indicates that, although the student prepares the gesture to produce the first syllable before the beginning of the movement, he also programs the movement to execute the second syllable (online planning), while still writing the first letter.

In addition, the search for information on the notebook screen may suggest that the student did not have a lexical memory of the word, thus requiring the interruption of writing for the conference and, later, the continuation of the writing of the word (Kandel & Perret, 2015).

Studies (Ellis & Young, 1988; Purcell et al., 2011) have reported that peripheral and central processes interact during writing. As Castles and Coltheart (1993) pointed out, the acquisition of writing demands that children master the correspondences between phonemes and graphemes, as this is not enough to achieve correct spelling. This process is even more challenging for children with dyslexia, as they fail to learn these correspondences, causing difficulties in writing words and establishing orthographic long-term memory. Binamé and Poncelet (2015) similarly stated, as already referred to in the literature (Ehri, 2005; Share, 1995), that phonological recoding skills are a prerequisite for the development of orthographic long-term memory. However, in a totally irregular situation where several graphemes may map one phoneme, phonological skills are insufficient for creating the detailed long-term orthographic representations required for producing conventional spelling, which might be the case for children with dyslexia.

Hence, we can see that schoolchildren with dyslexia had difficulties in accessing words (for both high and low frequency), with different orthographic rules, indicating that the average gaze is a good indicator to verify this interaction between the orthographic modules and the motor or that is, the production of handwriting demands the recovery of motor programs and the

preparation of movement and, thus, performing a greater number of pauses (Germano, & Capellini, 2019; Kandel & Perret, 2015; Sumner, Connelly & Barnett, 2013).

Such factors make writing more difficult for this population, especially for children, who may need more stimuli/support to integrate spelling knowledge.

5. Conclusion

We conclude that dyslexics perform a greater number of looking-up events to verify orthographic characteristics in high and low-frequency words, indicating that the central orthographic modules interfere with the motor programming of writing movement (peripheral processes-pauses).

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