Eye Movements of Beginning and more Skilled Readers

M Sardeira[1] & L Moniz Pereira[2]

[1,2]Centro Interdisciplinar para o Estudo da Performance Humana, Faculdade de Motricidade Humana, Universidade Técnica de Lisboa, Estrada da Costa, Cruz-Quebrada, Lisboa, PORTUGAL

[1]*marinasardeira@gmail.com*, [2]*lmpereira@fmh.utl.pt*

[1,2]*www.fmh.utl.pt/ciper*

ABSTRACT

The present study aimed to analyze and compare the eye movements of beginning (2nd grade) and more skilled (4th grade) readers, during reading words and pseudo-words aloud, that differ in frequency (just for words), regularity and length. In this way, one intends to analyze the process of visual information extraction, by both groups, and detect experience and practice-related changes in the ocular behavior. The eye movements of 34 children were monitored, while these were reading words/pseudo-words lists, and this was accomplished using eye-tracking technology.

The results show statistically significant differences between the two groups, in mean and total fixations duration for high-frequency words, in mean fixation duration for regular words and in the mean saccade amplitude in irregular pseudo-words. However, no significant differences were found between the groups on the study of the other variables. Nevertheless, the results suggest that skilled readers tend to show more effective eye movements, what determined a lesser effect of words' frequency, regularity and length on this group. Moreover, the pseudo-words processing was more difficult than that of words, in both groups.

1. INTRODUCTION

Eye movement research is a potentially powerful way to understand a wide variety of cognitive processes and their development, including reading (Karatekin, 2007). Eye movements are an inherent behavioral manifestation and a natural part of reading, allowing for the online analysis of this process (Radach & Kennedy, 2004) and providing information about the difficulty of the reading task for a given subject (Rayner, 1998).

The large body of literature concerning skilled adult readers' eye movements contrasts with the number of investigations about children's oculomotor control in reading. Very little is known about how this competence develops with age and how it relates to words' visual and linguistic characteristics, especially in childhood (Rayner, 1998; Aghababian & Nazir, 2000; Joseph et al., 2009).

Among the small amount of studies related to children's reading behavior, the large majority is about reading performance by English children, with few studies having been carried out to explain this behavior in others languages (Pinheiro, 1995). It is extremely relevant to develop eye movements experiments in European Portuguese, since this language has syllabic complexity and orthographic depth peculiarities that may affect decoding process (Seymour et al., 2003).

Nowadays, monitoring eye movements with eye-tracker technology is a frequent and well-established methodology, used in the study of adults' reading behavior. Nevertheless, it has been rarely applied with children (Joseph et al., 2009), having been used the reaction time or reading errors percentage, instead.

Reading, as part of a cultural evolution process, requires an increase of the subjects' skills such as locomotion or spoken language do (Rayner & Pollatsek, 1989). Hence, an important dimension of reading education includes the perception of how skilled reading develops (Ashby & Rayner, 2006). The reading act presents fundamental differences between beginning, intermediate and proficient adult readers (Spear-Swerling & Sternberg, 1996). Children's eye movements differ somewhat from those of adults. The ability to move the eyes from left to right as well as eye movements cognitive control change gradually, allowing children to focus on the relevant part of the word or text and to accomplish a more efficient information processing during fixations (Rayner & Pollatsek, 1989). Studies that have carefully controlled the region from which useful information can be extracted during a fixation in reading – perceptual span –

have showed that for English skilled readers this area extends 14-15 characters to the right of fixation and 3-4 characters to the left. Beginning readers, on the other hand, have a smaller perceptual span – about 11 characters to the right of fixation. Therefore, becoming proficient in reading requires the ability for a more efficient use of parafoveal information (Rayner, 1986), as beginning readers process less information in one fixation than skilled readers. Some investigators found that children in their 4th grade already show a perceptual span size comparable to that of adult skilled readers (Rayner, 1986; Häikiö et al., 2009).

Besides the developmental changes that have been well documented, the examination of experience and practice-related changes in ocular behavior in reading tasks involving the control of visual and linguistic characteristics of words/pseudo-words is of the greatest interest. This is due to the fact that very few investigations have been conducted to analyze these questions in childhood.

Stemming from what was previously exposed, the main goal of the present study is to analyze and compare the eye movements of beginning and more skilled readers, when reading words and pseudo-words aloud, that differ in length, frequency (just for words) and regularity. In this way, one intends to analyze the process of visual information extraction, by both groups, and detect experience and practice-related changes in the ocular behavior.

1.1   Length Effects

The word length is a visual factor (O'Regan, 1990) available from parafoveal and peripheral vision (Reichle, et al., 2006), that has been shown to affect eye movements.

Since the 1970s, researchers sought to clarify word length effect in adult skilled readers' eye movements. The experimental results show that length determines largely where to move the eyes and how long the eyes stay on a word (McConkie & Rayner, 1976, Rayner, 1998, for a review).

More recent research conducted with children found that readers performance decreases when word length increases (Aghababian & Nazir, 2000), which was apparent in the higher number of fixations and in gaze duration – sum of all fixations on a word prior to moving to another word – in long words (Hyönä & Olson, 1995; Joseph et al., 2009). This effect, however, can be attenuated with reading experience and practice. Therefore, beginning readers tend to exhibit a stronger word length effect than more skilled readers (Aghababian & Nazir, 2000; Bijeljac-Babic et al., 2004; Joseph et al., 2009). Studies developed in Portuguese language have shown similar results. Word length exerts a different influence on children reading behavior over the school years, as it is observed that this effect is higher in the first years of reading instruction (Pinheiro, 1995; Vale, 1999). One factor that contributes to the decrease of word length effect as reading experience builds up is the development of mental lexicon. Beginning readers take more time to initiate and complete lexical access than proficient readers, and therefore the familiarization with visual formats of words must be taken into account to explain this behavior. The decrease of the word length effect is observed after 5th grade and it suggests an adjustment between visual and lexical factors (Aghababian & Nazir, 2000). Other factor pointed out is that some oculomotor mechanisms required for a proficient reading aren't yet completely developed in beginning readers (Reichle et al., 2003).

According to an experiment developed by Luca et al. (2002), with Italian children who read lists of words and pseudo-words, the saccades amplitude increased with word length. In addition, this amplitude was higher in long words than in long pseudo-words and the number of saccades and regressions was higher in long pseudo-words than in words with the same length. When short words were compared with short pseudo-words, no differences were identified. The data also show that fixation duration tended to be superior in pseudo-words. Generally, pseudo-words were processed more difficultly than words. Similar conclusions were observed in Portuguese studies using reaction time methodology (Vale, 1999).

1.1.1   Initial Landing Position

The initial landing position is the region of a word that the eyes initially fixate after making a first pass saccade into that word (Joseph et al., 2009). The gaze direction is generally pointed at the center of the word or slightly left of it (McConkie et al., 1988; O'Regan, 1990), and this is usually called preferred viewing location (Rayner, 1979). Experiments in the word perception field show that the subjects' performance on word recognition varies with initial landing position (Nazir, 2000). The existence of a preferred viewing location is independent of word length and can be generalized over languages with different alphabetic writing systems and over different word recognitions tasks (Aghababian & Nazir, 2000).

The landing position effect has been more examined in adult readers than in children (Joseph et al., 2009). However, Grimes in 1989 reported that children in their first year of reading instruction show the same landing position patterns as adults. More recently, these results were corroborated by Aghababian and Nazir (2000) in experiments with children in 1st to 5th grade. In all grades tested, word recognition performance was

better when the child fixates regions in the word where a maximum of letters could be recognized, which was located slightly left of the center. Joseph et al. (2009) also provide an opportunity to analyze whether beginning readers – children with ages ranging from 7 to 11 years, and adult skilled readers differ in where words are fixated first. The results suggest the existence of minimal differences in fixation landing position between children and adults.

1.2   Frequency Effects

Word frequency is a linguistic feature that refers to the occurrence of a word in a language, reflecting the ease of the reader to identify a word, what naturally results from how many times it has been encountered before in reading (Blythe et al., 2009). High-frequency words have high rates of occurrence in language and are more likely to be familiar for readers than low-frequency words that are less encountered in language (Macedo et al., 2007).

The first studies which analyzed the frequency effect in eye movements have demonstrated that fixation durations on low-frequency words were longer than in high-frequency words (Rayner, 1977). Subsequent experiments controlling others variables (as word length) concluded that frequency still presents a robust effect in fixation times, specifically in first-fixation durations and in gaze duration (Rayner & Duffy, 1986; Rayner & Raney, 1996). The magnitude of frequency effect is usually fixated between 20-30 ms for first-fixation duration and single fixation duration and between 50-60 ms for gaze duration (Pollatsek et al., 2008). Furthermore, high-frequency words tend to be targeted by fewer fixations (Rayner & Raney, 1996). These results suggest that low-frequency words are more difficult to lexically access and to integrate in context (Rayner & Duffy, 1986; Reichle et al., 2006).

Investigations conducted with children verified that reading experience and practice have a positive effect in the diminishing of the frequency effect. Hence, more skilled readers tend to be less affected by word frequency than beginning readers (Vale, 1999; Aghababian & Nazir, 2000). However, independently of the reader proficiency level, an increase of the single fixation, first-fixation and gaze durations is observed, in low-frequency words (Blythe at al., 2009).

1.3   Regularity Effects

In contrast with the large amount of research that has been applied to the word frequency and word length subjects, few authors studied the words regularity effect.

Word regularity concerns the degree to which a word follows the spelling-sound correspondence rules (Sereno et al., 1998). Hence, regular words are those which can be read by the direct application of grapheme-phoneme correspondence, and irregular words, on the other hand, are those which cannot. Previous research has determined that regular words are identified faster than irregular words (Baron & Strawson, 1976). Stanovich and Bauer (1978), measuring reaction time, observed that regular words were read more quickly than irregular words by university students. These authors found that more skilled readers present a diminished word regularity effect. Other investigations, analyzing regularity effect when word frequency was controlled, showed that low-frequency irregular words tend to present higher reading times than low-frequency regular words. Contrarily, no such regularity effect has been observed in high-frequency words (Sereno & Rayner, 2000). Eye movements tracking experiments of subjects reading isolated words showed that word regularity seems to have a greater impact in first-fixation duration and gaze duration (Inhoff & Topolski, 1994; Sereno & Rayner, 2000).

Portuguese studies with children (Pinheiro, 1995: Vale, 1999) found results similar to the ones previously exposed. Portuguese native children tend to process regular words more easily than irregular words. However, regularity shows a greatest effect in the first years of instruction. This effect is present both in words and pseudo-words reading (Vale, 1999).

When the aforementioned studies are taken into consideration, one expects that, in the present study, the magnitude of word/ pseudo-word length, frequency (just for words) and regularity effects on eye movement measures will be greater in beginning readers than in more skilled readers, as a consequence of the inefficient oculomotor control and linguistic processing carried out by beginning readers. On the other hand, it is predictable that both groups show identical initial landing position.

2. METHODS

2.1 Participants

A total of forty children from 2nd and 4th grades of an elementary school in Lisbon took part in this experiment. Twenty of these children were selected from the 2nd grade and twenty from the 4th grade, according to the judgment of their respective teachers as normal or good readers, with normal or corrected-to-normal vision and no known reading difficulties. In order to make selection criteria more uniform, and to assess all children in a task similar to the one required for the study, a standard reading test named Word Recognition Test [*Prova de Reconhecimento de Palavras® (PRP)*] (Viana & Ribeiro, 2010) was applied. The criterion of inclusion adopted was having a performance in the normal range in the PRP, according to the scholar year. Therefore, only the eye movements of seventeen children from the second grade – 6 boys and 11 girls; mean age: 93,87 months – and seventeen children from the fourth grade – 10 boys and 7 girls; mean age: 117,41 month – were monitored.

All children's parents were informed about the purpose and procedure of the study, and they were asked to give their written consent for collecting and publishing the results, even if these are anonymous.

Data were collected between March and April of 2011, a period that falls approximately in the middle of the school year in Portugal.

2.2 Materials

The experimental stimuli used were Portuguese words and pseudo-words lists. Based on reading learning benchmarks established by the Portuguese Ministry of Education, these stimuli were selected from a Vale (1999) study, which aimed to assess children in word recognition tasks. The words present in this work result from a careful selection procedure, and are classified according to frequency, regularity and length. Pseudo-words were generated from the word stimuli, by replacing one or two graphemes (mostly consonants). The syllabic format was not affected in this process. Examples of word and the respective pseudo-word pair are: três-drês, bailarina-daibarina, leal-deal and gladiador-cladianor.

The lists used in the experimental procedure of the present study contained eight items, displayed in two rows of four. There were two lists of words and two lists of pseudo-words, for a total of 16 words and 16 pseudo-words. This design has been previously used by Luca et al. (2002).

2.3 Apparatus

Children's eye movements were monitored using the Applied Science Laboratories (ASL) Model 504 remote eye-tracker system. Although participants read binocularly, just monocular eye movements from the right eye were recorded, with the refresh rate set to 60 Hz. The stimuli were present on a 15 in. LCD computer monitor interfaced with the eye-tracker. Words and pseudo-words were written in black, size 40 Arial font, on a light gray background and they were presented at a viewing distance of 85 cm.

2.4 Procedure

Data collection was performed with each child individually. At the beginning of the experiment, participants were informed about the purpose and the procedure of the research. Although parental written consent was already assured, all children were asked about their willingness to participate in the study.

The room luminance was diminished and the children were instructed to sit in a stationary chair in front of the computer monitor and to lay their head in a headrest, to minimize head movements that may contribute to a decrease in the eye-tracker's accuracy. They were also asked to stay as still as possible.

An initial calibration procedure of the eye-tracker was carried out. Each child was instructed to look at a sequence of nine fixation points, numbered from left to right and from top to bottom, in ascending order, while their fixation position on each point was being recorded.

Once the eye-tracker had been properly calibrated, the children were asked to normally read aloud the items presented in the computer monitor. The experiment lasted between 7-10 min.

2.5 Variables

The choice of the dependent variables was based in the literature revision and in the measuring capabilities of the eye-tracker used to record the data. Hence, the average value over every words of the following items have been analyzed for each child: fixation number – fixations made in a word/pseudo-word; first-fixation duration – duration of the first-fixation on a word/pseudo-word; total reading time – sum of all fixations including regressive ones in a word/pseudo-word; mean fixation duration – average of fixation durations in a word/pseudo-word; saccades amplitude – length of the saccades made on the word/pseudo-word; number of regressions – regressive fixations on the word/pseudo-word; and initial landing position – landing region of first-fixation on the word/pseudo-word. To analyze landing position, each word was divided into five equally

sized zones, independently of graphemic structure, procedure which has been previously used by Aghababian and Nazir (2000). The results presented in section 3 are the average of these values over each group (2nd and 4th grades).

The independent variables considered were length – short and long word/pseudo-words, frequency – high and low-frequency words, and regularity – regular and irregular words/pseudo-words. The independent variable school grade was used to form the groups.

2.6   Analyses

Initially, the children gaze direction and the associated data were processed with software of ASL. For each word and pseudo-word the number of fixations, first-fixation duration, the average of fixation duration, total reading time, saccades amplitude, number of regressions and initial landing position were determined.

Data were inserted in Statistical Package for Social Sciences® (SPSS) software and all the descriptive and comparative statistical analysis was executed with this tool. To compare the two groups, multivariate analysis of variance – MANOVA has been used. If statistical differences between groups were detected, univariate analysis – ANOVA – was then applied to identify the dependent variables responsible for the differences. However, it is possible to have a significant multivariate test, with the univariate tests turning out to be insignificant. This may occur due to accumulation of the evidence from the individual variables in the overall test, although individually those evidences are not strong enough. Even so, we decided to use multivariate test to control type-one error rates (Afifi et al., 2004). To overcome this situation, when univariate tests were unable to detect the dependent variable(s) responsible for the differences between groups, to have a hint on which variables may be the most important in that outcome, an overlap interval was calculated – given a certain dependent variable distribution, the interval is defined as ranging from the mean value minus the standard deviation to the mean value plus the standard deviation, for a given grade. Then, when comparing that variable distribution in the 2nd and 4th grade, one looks for the percentage of overlap between the two intervals:

$$\frac{\text{intervals overlap}}{\text{intervals mean length}} \times 100\%$$

Discriminate analysis and logistic regression were not used because of the data characteristics, namely, the multicollinearity of some variables and the reduced number of data instances.

3. RESULTS

Global analyses were conducted in order to explore oculomotor behavior of beginning and more skilled readers, during reading of words/pseudo-words with different length, frequency (just for words) and regularity. Statistically significant differences between groups were analyzed with a multivariate analysis of variance.

*3.1   Word and pseudo-word length analysis*

Table 1 shows that beginning readers made more and longer fixations, longer saccades and more regressions in longer words. The same is observed in pseudo-words reading. More skilled readers show an identical ocular behavior when short and long words were compared. An exception must be made for the mean fixation duration, which decreased with word length. In pseudo-words reading, children from 4th grade made longer fixations in short pseudo-words. On the other hand, the number of fixations, regressions, saccades amplitude and the total reading time increased with pseudo-words length.

Comparing the eye movement of both groups, it was possible to verify that, globally, 2nd grade children made more fixations and regressions, longer saccades and presented a longer total reading time than 4th grade children. However, more skilled readers generally showed higher fixation durations (first-fixation and/or mean fixations durations) in short and in long words, and also in short pseudo-words.

The initial landing position is represented on Figure 1. In short words, both groups showed a clear preference for region 3, i.e., the middle portion of words. On the other hand, in long words the preferred position of initial landing was region 2, slightly left of the center, both by beginning and more skilled readers.

Table 1. *Mean and standard deviation (in parentheses) of eye movement measures: beginning (2nd grade) and more skilled readers (4th grade); short and long words and pseudo-words. NF – number of fixations; FFD – first-fixation duration; MFD – mean fixations duration; TRT – total reading time; SA – saccade amplitude (ETU – Eye-Tracker Units); NR – number of regressions.*

			NF	FFD (ms)	MFD (ms)	TRT (ms)	SA (ETU)	NR
Words	Short	2nd grade	4,88 (1,35)	0,23 (0,07)	0,23 (0,04)	1,11 (0,46)	10,25 (1,93)	1,56 (0,62)
		4th grade	4,28 (1,73)	0,24 (0,07)	0,24 (0,06)	0,93 (0,40)	9,97 (2,06)	1,54 (0,84)
	Long	2nd grade	7,93 (2,09)	0,27 (0,06)	0,24 (0,04)	1,89 (0,06)	12,43 (1,93)	2,13 (0,95)
		4th grade	7,51 (2,37)	0,25 (0,06)	0,23 (0,03)	1,67 (0,47)	12,16 (1,98)	2,17 (0,89)
Pseudo-Words	Short	2nd grade	6,07 (1,66)	0,23 (0,08)	0,24 (0,04)	1,40 (0,57)	11,52 (3,23)	2,23 (0,82)
		4th grade	4,57 (1,56)	0,24 (0,08)	0,25 (0,04)	1,08 (0,31)	8,81 (1,15)	1,61 (0,76)
	Long	2nd grade	9,15 (2,72)	0,27 (0,08)	0,25 (0,04)	2,22 (0,83)	11,61 (1,41)	2,35 (1,11)
		4th grade	8,56 (2,30)	0,22 (0,05)	0,24 (0,03)	1,95 (0,51)	10,79 (0,75)	2,25 (0,99)
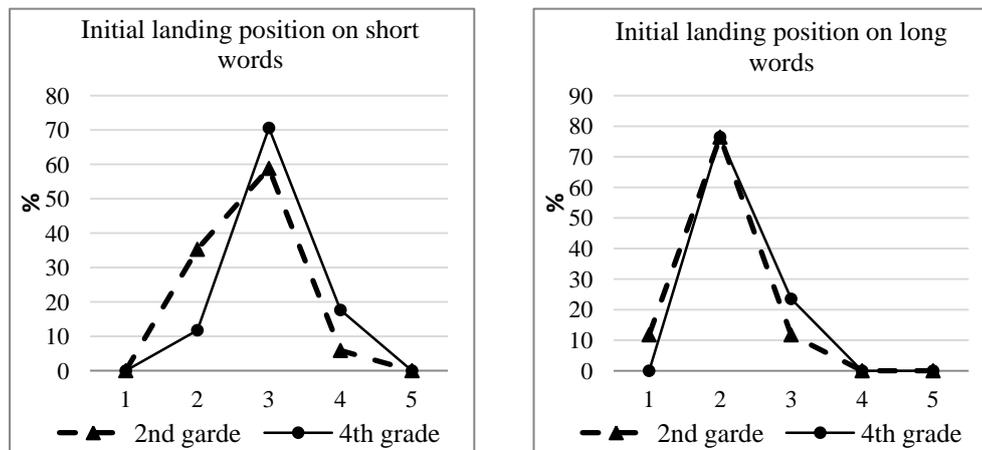
Figure 1. *Initial landing position per fixation region of: beginning (2nd grade) and more skilled readers (4th grade); short (left side) and long words (right side).*

The MANOVA implementation used to compare groups showed that for short words no significant differences were observed $\left(\text{Wilks}'F_{[7,24]} = 1,662, p = 0,549 > 0,05 = significance\ level\right)$ and the same was verified for long words $\left(\text{Wilks}'F_{[7,24]} = 0,862, p = 0,549 > 0,05\right)$, for short pseudo-word $\left(\text{Wilks}'F_{[6,25]} = 1,842, p = 0,130 > 0,05\right)$ and for long pseudo-word $\left(\text{Wilks}'F_{[6,25]} = 2,372, p = 0,058 > 0,05\right)$.

3.2 Word frequency analysis

The results presented in Table 2 show that beginning readers made more and longer fixations, more regressions and a longer total reading time in low-frequency words. Saccades amplitude decreased in low-frequency words. Similar behavior was shown by more skilled readers, except for first-fixation duration, which remained unchanged in low-frequency words.

Comparing the descriptive statistics of both groups, it is evident that beginning readers showed a marginal increase in the fixations number, less regressions, longer reading time, longer saccades length and similar first-fixation duration, in high-frequency words. Mean fixation duration was superior in 4th grade children. In low-frequency words, the 2nd grade children presented more fixations and regressions, longer first-fixation durations and total reading time, identical mean fixation durations and saccades amplitude.

Table 2. *Mean and standard deviation (in parentheses) of eye movement measures of: beginning (2nd grade) and more skilled readers (4th grade); high- and low-frequency words.*

			NF	FFD (ms)	MFD (ms)	TRT (ms)	SA (ETU)	NR
Words	High-frequency	2nd grade	5,16 (1,68)	0,24 (0,05)	0,22 (0,03)	1,14 (0,45)	12,06 (2,03)	1,45 (0,75)
		4th grade	5,05 (1,79)	0,24 (0,05)	0,23 (0,04)	1,06 (0,32)	11,48 (2,49)	1,61 (0,69)
	Low-frequency	2nd grade	7,65 (1,70)	0,26 (0,07)	0,25 (0,05)	1,85 (0,64)	10,62 (0,80)	2,24 (0,72)
		4th grade	6,65 (2,09)	0,24 (0,07)	0,25 (0,05)	1,52 (0,43)	10,63 (1,67)	2,04 (0,94)

For high-frequency words, MANOVA suggests the existence of statistically significant differences between beginning and more skilled readers $\left(\text{Wilks}'F_{[6,26]} = 3,552, p = 0,011 < 0,05\right)$. However, the ANOVA univariate analyses were unable to identify which variables cause these differences (ps > 0,0083). Hence, the overlap interval was calculated for all dependent variables. The results obtained show that mean fixation duration (77% overlap) and total reading time (83% overlapped) variables could be responsible for the differences identified in multivariate analysis. For low-frequency words, eye movements of both groups didn't differ significantly $\left(\text{Wilks}'F_{[6,26]} = 1,105, p = 0,386 > 0,05\right)$.

3.3 Word and pseudo-word regularity analysis

The eye movement measurements shown in Table 3 indicate that beginning readers increased fixations number and duration, regressions, total reading time and saccades amplitude, for irregular words. In pseudo-words reading, this group made less fixations and regressions and presented a shorter total reading time in irregular pseudo-words. Saccades amplitude and the mean fixations duration increased in pseudo-words.

More skilled readers, in turn, showed more fixations and regressions, longer total reading time and higher saccades amplitude in regular words. Similar results were obtained in fixations duration. In irregular pseudo-words reading, this group decreased the number of fixations and regressions, saccades amplitude and total reading time comparing to regular pseudo-words, but they increased fixations duration.

Comparing both groups, it was verified that in regular words beginning readers made slightly more fixations, less regressions, shorter saccades, lower fixation durations and presented a total reading time scarcely higher than skilled readers. In general, in irregular words and in pseudo-words reading, beginning readers display increased eye movements measures.

Table 3. *Mean and standard deviation (in parentheses) of eye movement measures of: beginning (2nd grade) and more skilled readers (4th grade); regular and irregular words and pseudo-words.*

			NF	FFD (ms)	MFD (ms)	TRT (ms)	SA (ETU)	NR
Words	Regular	2nd grade	6,25 (1,33)	0,24 (0,04)	0,22 (0,03)	1,37 (0,40)	11,11 (1,32)	1,68 (0,62)
		4th grade	6,10 (1,94)	0,24 (0,05)	0,24 (0,04)	1,32 (0,37)	11,41 (2,75)	1,89 (0,80)
	Irregular	2nd grade	6,56 (2,05)	0,25 (0,07)	0,25 (0,04)	1,63 (0,69)	11,57 (2,02)	2,01 (0,97)
		4th grade	5,69 (2,09)	0,24 (0,05)	0,24 (0,04)	1,28 (0,40)	10,72 (1,51)	1,82 (0,84)
Pseudo-Words	Regular	2nd grade	7,80 (2,12)	0,25 (0,06)	0,24 (0,03)	1,83 (0,69)	11,07 (2,51)	2,32 (0,99)
		4th grade	6,86 (2,36)	0,23 (0,06)	0,23 (0,03)	1,52 (0,51)	9,92 (1,10)	1,96 (1,00)
	Irregular	2nd grade	7,42 (2,22)	0,25 (0,06)	0,25 (0,04)	1,79 (0,70)	11,43 (1,75)	2,27 (0,87)
		4th grade	6,27 (1,50)	0,24 (0,06)	0,26 (0,03)	1,51 (0,32)	9,68 (1,03)	1,90 (0,78)

Analyzing MANOVA results, statistically significant differences were found between the two groups in regular words $\left(\text{Wilks}'F_{[6,26]} = 2,635, p = 0,04 < 0,05\right)$. The overlap interval for each variable was calculated, and the results obtained reveal that there is evidence for the mean fixations duration variable (71% overlap) to be identified as the responsible for the differences between beginning and more skilled readers. Statistically significant differences were also observed in irregular pseudo-words reading $\left(\text{Wilks}'F_{[6,25]} = 2,896, p = 0,027 < 0,05\right)$. An ANOVA test has shown that the variable responsible for the differences between groups is saccades amplitude (p = 0,002 < 0,0083). No differences

were reported in irregular words $\left(Wilks'F_{[6,25]} = 0,091, p = 0,509 > 0,05 \right)$ and in regular pseudo-words reading $\left(Wilks'F_{[6,25]} = 1,697, p = 0,163 > 0,05 \right)$.

4. DISCUSSION

The present study investigated the eye movements of beginning (2nd grade) and more skilled (4th grade) readers, during the reading aloud of words and pseudo-words, which differ in frequency (just for words), regularity and length. In this way, one intended to analyze the process of visual information extraction, by both groups, and detect experience and practice related changes in the ocular behavior.

The results obtained by beginning and more skilled readers indicate that word length increased the fixations number, what support the perspective of length has a visual factor that modulates the refixation probability. Thus, refixations are not only determined by linguist factors (Joseph et al., 2009). It is also evident from the results that children performance deteriorated with length, which is explained by the limits of acuity: when the word/pseudo-word becomes longer, more letters fall in low resolution visual areas (Aghababian & Nazir, 2000). Long words and long pseudo-words were more difficult to process by all children, as demonstrated by the increase of saccades amplitude and number of fixations, a tendency already observed in previous research (Vale, 1999; Joseph et al., 2009). No statistically significant differences were found between beginning and more skilled readers as in the Joseph et al., (2009) study, with children of the same ages. Although it is apparent in the descriptive eye movement results (Table 1) that experience and practice in reading tend to improve children performance, the collected data didn't reveal that beginning readers were significantly more affected by word length than more skilled readers. The same effect was observed in Aghababian and Nazir (2000) results, but in a significantly way. In the present study, it was verified that more proficient readers tend to have longer fixations duration, but fewer fixations in short word and pseudo-words reading. This ocular behavior suggests the adoption of visual strategies that decreased total reading time, and consequently increased their reading performance. It was also observed that more skilled readers decreased fixations duration in long words, a tendency analogous to the beginning reader's behavior.

As for the analysis of initial landing position, the results obtained show that readers tended to initially fixate the center or a region slightly left of it, and to lesser extent the word's extremities. These results support earlier studies (O'Regan, 1990; Nazir, 1998) and recent models – E-Z Reader (Reichle et al., 2006) that tries to explain eye movements in skilled reading. It was observed that word length contributes to modulate initial landing position on word, what suggests that children process length information across parafoveal vision. This kind of information allows children to program saccades to the optimal viewing position (Joseph et al., 2009). Globally, comparing beginning and more skilled readers, these groups didn't differ significantly in the location of the first fixation, a trend that is in agreement with other investigations (Aghababian & Nazir, 2000).

Eye movements of both groups were affected by word frequency. Longer and more fixations, more regressions and the decrease of saccades' amplitude, presented by both groups of readers, denote more difficulty in low-frequency words processing. Previous studies (e.g. Rayner & Duffy, 1986; Rayner & Raney, 1996; Blythe et al., 2009) have demonstrated a similar effect of frequency in total reading time, first-fixation duration and number of fixations. However, in the present study, more skilled readers didn't increase first-fixation duration in low-frequency words. Since this variable is modulated by the determination of word familiarity, this processing stage was expected to occur more rapidly in high-frequency words (Reichle et al., 2006). These results suggest that more skilled readers are able to quickly detect if the word is familiar, making other fixations on that word to extract relevant information which may help in the grapheme-phoneme conversion process.

Comparing beginning and more skilled readers when word frequency was modulated, statistically significant differences were identified in the mean fixations duration, in high-frequency words. More skilled readers tended to make longer fixations in words, but in smaller numbers. Globally, the word frequency has a higher impact in the eye movements of beginning readers than in more skilled readers. This fact suggests that experience and practice tend to attenuate frequency effect as demonstrated by Vale (1999).

Prior work has documented that regularity mainly affects children in an initial stage of reading instruction (Stanovich & Bauer, 1978; Pinheiro, 1995, Vale, 1999; Sereno & Rayner, 2000). In the present work, the results suggest (particularly the mean values variation amplitude of mean fixations duration and total reading time) that beginning readers were more affected by regularity than more skilled readers. It was observed that children from 4th grade decreased substantially the saccades' amplitude, in contrast to 2nd grade children in irregular words and pseudo-word reading. This indicates the use of a visual strategy to read words with some peculiarities, as irregular words are. Beginning readers usually made longer saccades, what leads to the

extraction of more information from parafoveal view and consequently consumes more time. In general, children tended to process regular words more easily than irregular words, but the same was not observed in pseudo-words reading, in contradiction to the results obtained by Pinheiro (1995) and Vale (1999). Comparing both groups, significant differences were identified in mean fixations durations in regular words and in saccades' amplitude in irregular pseudo-words.

When trying to extract a global pattern in the eye movement measurements for words and pseudo-words reading, it was verified that pseudo-words were more difficult to process than words. These results seem logical, since pseudo-words are not contained in the children's mental lexicon, what requires more time to be spent in the evaluation of the word's familiarity, and also a sequential grapheme-phoneme conversion of small parts of the word, what immediately penalizes children reading performance. The same was observed in low-frequency words, which are not processed by a rapid global analysis. Both groups made more fixations and regressions and presented a higher total reading time in pseudo-words and in low-frequency words, results that show the presence of harder processing challenges.

5. CONCLUSIONS

Overall, the analysis of the eye movements measurements obtained in this study suggests a positive effect of reading experience and practice in visual information extraction quality. However, not many statistically significant differences were found between beginning and more skilled groups of readers, as defined in this study. The collected data show a high intra-group variability in eye movement measurements (reflected in large standard deviations), what suggests that in these ages oculomotor behavior is not yet sufficiently organized to allow for a distinctive group-labeling pattern to arise. The child's own vocabulary may also differ substantially between individuals, enhancing a dispersive effect that prevents stronger statistical differences to be found.

It is important to conduct more investigations in this field, since the analysis of reading behaviors has the power to allow for the detection of deviant reading behavior and may help to infer the reading impairment causes and point the direction of effective intervention methodologies.

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