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The Effect of Features of Text (Word Length and Frequency) on the Iranian Dyslexic Students' Eye Movements

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ABSTRACT

Background: This study aimed to investigate the impact of frequency and word length on the eye movements in dyslexic students while they were reading Persian textbooks.

Methods: The method applied to this study was quasi-experimental. The statistical population consisted of 56 male and female students in first, second, and third grades, referring to Learning Disorder Centers of Educational Organization in 2 and 10 districts in Tehran. Twenty-five students with dyslexia were selected using the available sampling method (participants included 12 boys and 13 girls who were in second, third, fourth, and fifth grade with 6, 8, 8, and 3 students, respectively). The eye-tracking device, SMI-RED-120Hz, was used for data collection. The multivariate analysis of variance (MANOVA) method was applied to analyze the data.

Results: There are two significant findings: the effect of words' length on the number of fixation, fixation time, and the number of regression, as well as the effect of words' frequency on the number of fixation, fixation time, and the number of regressions.

Conclusion: Frequency and word length on fixation and regression play an important role in the process of reading in dyslexic students.

Introduction

Dyslexia refers to difficulties in acquiring writing, reading, and reading skills such as phonological decoding and word identification. Dyslexia is not caused by extraneous factors such as socioeconomic status, sensory acuity deficits, general learning difficulties, or similar factors [1]. According to the fifth edition of the Diagnostic and Statistical Manual of Mental Disorders (DSM-V), definition of dyslexia refers to *a state in which reading progress is lower than the expected level* (according to child's age, IQ, and education). This disability prevents academic achievement or daily activities required by reading to a great extent [2]. Dyslexia causes problems in comprehension, reduces reading experience, and prevents the growth of vocabulary and knowledge [3]. Dyslexic children have difficulty reading words through phonetic-phonological routes [4]. Students' proficiency in phonological processing and understanding phonemic relations is a powerful factor in determining students' success in reading performance [5]. According to DSM-V, in the case of a co-occurring neurological or sensory disorder with a reading disability, the severity of reading disability is greater than when reading disability co-occurs with other disorders [2]. Also, the basic components of reading include knowing the letters, putting them in the form of a word, and understanding the meaning and its application in the text [4]. In fact,

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dyslexia is a type of disorder that includes confusing similar words and guessing words by looking at the initial and final letters of the words. It also includes mirror reading, severe difficulty in spelling words, lack of motivation, disgust with reading, and difficulty detecting components of the whole [6].

Reading requires a complex and healthy nervous system that links many nerve cells, visual centers, language, and memory. Children suffering from the reading disorder move their heads instead of their eyes during reading, read word by word with pulled voice and monotonously, do not pay attention to punctuation, ignore the meaning of the word, guess the words unrelated to the content, and phonetic elements, and displace or repeat words that have just been read [7].

Reading from the attention phase to word recognition and comprehension is an activity that requires the effective integration of several central cognitive systems [8]. The beginning of the reading process can be understood as the connection between eye and line, in other words, paying attention to the text to capture visual information [9]. Attention has been considered an essential and integral part of reading skills, and it is stated that this element is vital for reading texts fluently [10]. The next key step in the reading process is to recognize the letters, their sounds, and, in sum, the words [11]. Finally, reading comprehension is obtained by understanding and interpreting the interaction between the words and the links between them. The above steps are essential to forming the reading process, and any deficiencies in each step and the system will disrupt the entire reading process [12]. There are many approaches to studying reading; one is to examine eye movements during reading. Eye movement examination is probably the best way to examine the reading process [13-15].

Many cognitive processes (encoding, recognition, and decoding) involved in reading can be found by studying and tracking eye movements while reading. To achieve this goal, recording eye movements during reading can be exploited. Eye-tracking is a technique that allows the examiner to determine one's eye movement and fixation. The eyes move almost simultaneously across the screen, but their movement is not continuous [16]. Eye movements while reading, just like the time when we look at an object moving slowly, is not smooth and monotonous, but it is a set of the saccade across the line. These movements, saccades, and intervals during which the eye relaxes are named fixation. The eye movements during reading are similar to the movements while looking at various objects in a room in which the eye moves from one point to another [17]. The average fixation period is 225 milliseconds, including the duration of encoding and the time needed to plan and move the eye to the next word. The amount of time a reader fixes his sight on words is determined by several factors, such as the difficulty of that word [18]. A saccade is another type of eye movement, which is the rapid movement of the eye. It is often forward-directed and focuses on the next section of the text [10, 18]. The saccades are not always forward-directed; the regressions include backward-directed movements in the text, reflecting the reader's confusion [19]. The eye is substantially blind during the saccade, and most information is processed during fixation, which includes more than 90% of the total reading time [20]. While reading the text, most words are only fixed once. However, some words are fixed twice, or some others are not fixed at all. Since fixation is done on almost all of the words or their adjacent spaces, it seems that the main goal of the eye movement is to bring all the words close to Fovea, that is, a region in the center of the vision where the poor detail is processed better as opposed to anywhere else. There are three possible ways to measure word processing time. First is the duration of the first fixation, the second possibility is fixations, which is the total duration of the fixation on the word before the eye moves, and the third is the total time of sight, which includes subsequent fixations on the word and is the result of regressions [16].

The eye-tracking technique has been used to study behavior in scanning, driving, calculating, deductive reasoning, and reading. In such areas, researchers analyze eye movements according to fixations (maintaining the visual gaze on attended areas of text) and saccades (A quick move between fixations) [21].

Eye movement behavior during reading has been studied in many Latin languages (English, German, and French), particularly Chinese, Japanese, and Hebrew. Also, several studies have been conducted on eye movements during reading of ordinary people in Farsi with an eye movement monitoring device [15]. One of the problems that Iranian students are afflicted by is reading. Examining the results of the last 20 years of PIRLS international assessment reveals that most of the time, Iran has been ranked last in the international ranking. However, the PIRLS assessment is not exclusively carried out on dyslexic or normal readers. Dyslexia is an issue by which reading can be better understood. Therefore, research on eye movement monitoring in children with reading difficulties in Farsi is important because it provides accurate data on how dyslexic children read. In addition, this study may be considered an important step in determining the pattern of eye movements in children with reading difficulties and possibly finding ways to identify dyslexia. This study aims to assess the effect of features of text (word length and frequency) on the eye movements of students with dyslexia. Therefore, the research hypothesis is as follows: Eye movements (fixation and regression) of dyslexic students vary according to the frequency and length of the word while reading a text in Persian.

Methods

The research's method was quasi-experimental. Data collection was done through eye-tracking hardware. Data analysis was performed by repeated measure test. The eye-tracking device 120 Hz-RED-SMI model was used to measure dependent variables during reading. This device includes a 55-inch screen for presenting stimulus, an Infrared Wave Receiver for recording eye movements with a sampling speed of 958 Hz per second, X iView software for recording eye movements and changes, center experiment software for designing the experiment,

and ways of stimulus presentation and Begaze software for analyzing recorded data.

Participants

The statistical population consisted of 56 male and female students ranging from the first to the third grade of elementary school, referring to Learning Disorder Centers of Educational Organization in 2 and 10 districts in Tehran. Twenty-five of these students with dyslexia were selected using the available sampling method. The rationale behind using the available sampling method was that dyslexic students are spread in all schools; therefore, getting access to them is difficult. Participants consisted of 6 second-grade students, 8 third-grade students, 8 fourth-grade students, and 3 fifth-grade students, including 12 boys and 13 girls. The average age of participants was 9.3, and the standard deviation was 1. For each grade, the final text of the Persian textbook with Koodak font (a Farsi font) appeared on the screen. The test was carried out in the last month of the academic year (May) because, at that time, students had learned all book contents, and reading the first lesson of the next grade was not difficult for them. Concerning the ethical issues of research on subjects, this research was carried out with official permission obtained from the Center for Learning Disorder of Educational Organization in 2 district in Tehran.

Stimuli

Farsi textbooks (Reading books) of the First to Sixth grade of elementary school were chosen. To avoid interference of previous learning with students' performance, the first lesson of each grade's book was selected for students of the previous grade. The texts were selected to be similar in font and size to school books and also in difficulty level of words.

Twenty elementary school teachers were asked to divide the text's words into two high frequent and low frequent categories to categorize words in the high and low frequencies. Based on the frequency culture of Bijan Khan and Mohseni [22], the teachers' selection accuracy regarding the frequency of words was confirmed. Also, two-letter, three-letter, and words with more than three letters were categorized as short, average, and long, respectively.

Procedure

Before beginning the research, parents have completed informed consent, and subjects have been told that collected data would be kept confidential. Subjects were individually placed in front of the screen of the eye tracking device. After preparation and adaptation to the physical specifications of the subject, the device was used to complete the validation step. At this stage, the measurement error of the device was calculated separately for each subject. In cases in which the errors exceeded the acceptable range, that was 5 mm in this study; the adjusting stage was re-performed. Those subjects were omitted from the experiment in case of repeating high errors. After the validation phase, the subjects were told to look at some short sentences and read each of them aloud. While reading, the eye tracking device was recording their eye movements. At first, validation indicators of measures were calculated for all participants who are 0/7 degree, 0/65 degree, and 94 percent, respectively, according to measures reported in previous studies, which shows a proper data validity for analysis.

Results

Mean and standard deviations of dependent variables (number of fixation, length of fixation, and number of regression) have been shown in Table 1 based on the levels of independent variables (word length: short, long; word frequency: low, high).

To investigate the effect of the two independent variables on ocular indexes, the analysis of variance with repeated measures was used for each independent variable separately.

The results of the analysis of variance for investigating the effect of word length on ocular indexes are presented in Table 2. The assumption of data sphericity was confirmed due to the two levels of the between-subjects variable.

Regarding the results of the analysis presented in Table 2, it is approved that the effect of word length on all three dependent variables is significant. That is, short and long words affect the number of fixations, the length of fixation, and the number of regression on the words while reading the text. Thus, according to Table 1, the number of fixations and regressions on long words is significantly more than in short words. The length of fixations on long words is also longer than on short words. The amount of Eta squared, as an indicator of the effect size of the independent variables, reveals that 71 percent of changes in the number of eye fixation, 34 percent of changes in eye fixation length, and 50 percent of changes in the number of regressions are explained by the word length.

The results of the analysis of variance with repeated measures for investigating the effect of word frequency on ocular indexes are presented in Table 3. The assumption of data sphericity was confirmed due to the two levels of the between-subjects variable.

Regarding the results of the analysis presented in Table 3, it is approved that the effect of word frequency on all three dependent variables is significant. Low and high word frequency affect the number of fixations, the length of fixation, and the number of regression on the words while reading the text. Thus, according to Table 1, the number of fixations and regressions on low-frequency words is significantly more than on high-frequency words. Also, the length of fixations on low-frequency words is also longer than on high-frequency words. The amount of Eta squared, as an indicator of the effect size of the independent variables, reveals that 68 percent of changes in the number of eye fixation, 20 percent of changes in eye fixation length, and 59 percent of changes in the number of regressions are explained by the word frequency.

Discussion

The present study examined the effect of frequency and

Table 1: Descriptive measures of dependent variables (milliseconds)

Independent variables		Number of fixation		Length of fixation		Number of regression	
		M	SD	M	SD	M	SD
Word length	Short	3.8	2.9	435	203	4.4	3.9
	Long	6.4	2.7	509	200	6.2	3.6
	Total	5.1	2.6	472	188	5.3	3.7
Word frequency	Low	8.2	4.2	659	235	6	3.5
	High	4.8	4.3	538	172	4.4	4
	Total	6.5	4.1	599	188	5.2	3.7

Table 2: The results of the analysis of variance for investigating the effect of word length on ocular indexes

Sources	Elements	SS	Df	MS	F	Sig.	Eta squared
Word length	Number of fixation	176	1	176	72	0.01	0.71
	Length of fixation	218768	1	218768	15.1	0.01	0.34
	Number of regression	41.6	1	41.6	30	0.01	0.5
Error	Number of fixation	70	29	2.4			
	Length of fixation	419424	29	14462			
	Number of regression	40.3	29	1.4			

Table 3: The results of the analysis of variance for investigating the effect of word frequency on ocular indexes

Sources	Element	SS	Df	MS	F	Sig.	Eta squared
Word frequency	Number of fixation	104	1	104	62	0.01	0.68
	Length of fixation	82436	1	82436	7.5	0.01	0.2
	Number of regression	50.4	1	50.4	41.6	0.01	0.59
Error	Number of fixation	48.4	29	1.6			
	Length of fixation	316536	29	10915			
	Number of regression	35	29	1.2			

word length on the eye movement of dyslexic students while reading the text of the Persian book with an eye movement monitor device. The results of this study are significant regarding the effect of word frequency on eye movement. The number of fixations, the length of the fixation, and the number of regression on low-frequent words are significantly more than the high-frequent word in the text. As a possible explanation, it can be said that slower reading of words is due to a combination of factors, including inefficient visual coding, shared attention, and weak eye movement control. An increase in the number of regressions and fixations on low-frequency words is caused by the weak eye movement control of dyslexic children. This finding is consistent with the findings of Al Dahhan, Kirby, Brien, and Munoz [23] and Engbert, Nuthmann, Richter, and Kliegl [24].

Regarding the effect of word length on eye movement (fixation and regression) during reading, the text results are significant, and they are consistent with the results of research carried out in other languages, such as Rayner [25] and Tiffin-Richards and Schroeder [26]. This means that the word's length significantly affects the number of fixations, the length of fixation, and regression. In other words, when the word was long (4 letters and more), the average number of fixations and regressions increased, but when the word was short (2 to 3 letters), an average number of fixations and regressions reduced; in this regard, Morris, Rayner, and Pollatsek [27] demonstrated that the reason why word length affects the number of fixation, length of fixation and regression is that the eyes are guided with the help of calculations based on the boundaries of words (beginning and end of each word) that are marked with spaces. In addition, the eyes' tendency to jump over spaces between words is formed by eye calculations based on the shape and position created by the word boundary [16]. In a study, Sharifi, Farahani, Shahbazi, Sharifi, Kello, and Zare [28] revealed that simultaneous activation of brain regions responsible for speech and visual processing reduces reading speed.

The results of this research are consistent with the results of studies in other languages conducted by Liversedge, Drieghe, Yan, Bai, and Hyönä [29] that examine the significant effect of the word length on the variables of the fixation time, the number of saccades, the duration of the first fixation, the length of reading, and regressions. In this study, the effect of the word length on the fixation time and the total reading time was matched with the effect of word length on reading words in Chinese, which Wang found out, Pomplun, Chen, Ko, and Rayner [30]. In terms of word length, frequency, and predictability of the text, the results also showed a significant effect on the fixation time, the number of fixations, and the number of saccades.

Thus, it can be stated that when the word length decreases, the probability of saccadic movement on that word increases, and the probability of fixation and re-fixation decreases. Conversely, when reading long words, the number of fixation and fixation time increases [14]. This is in keeping with the findings of Tiffin-Richards and Schroeder [26].

One potential limitation is the time of day when dyslexic students begin to read; some students have been tested in the morning and others in the afternoon. It made it almost impossible to control time and issues related to biorhythm in students.

Conclusion

Practical suggestions: The reading process for dyslexic readers can be improved using short or medium-long words. As for word frequency, it is better to use high-frequency words in the text. In addition, this type of study requires further research with a larger sample size using the control group to compare normal and dyslexic groups of readers. These types of research ultimately determine the pattern of eye movements in both normal and dyslexic readers.

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Conflict of Interest: None declared.

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