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# Investigating the Effect of Different Levels of Reading Skills in English on the Features of Oculomotor Activity in 9-10-Year-Old Children

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**Abstract**

The purpose of the study is to examine the characteristics of oculomotor activity in children, aged 9 to 10, who have varying degrees of proficiency in reading English when it comes to identifying units situated in the parafovea and on the edge of the foveal region. The connection between reading and parafoveal vision has been extensively studied; data for adult normotypical readers are available, but information for younger readers is lacking. 49 kids between the ages of 9 and 10 are involved in the study. The Standardized Method for Studying Reading Skills in English was used to evaluate English reading comprehension (Kornev, 2010). The colored progressive matrices developed by Raven et al. (2012) were used to measure nonverbal intelligence. We observed the informants' eye movements while they worked on an exercise designed to improve their angle of visual attention. Using Eye Link 1000+ equipment and a sampling rate of 1000 Hz, eye movements were recorded. The informant was seated in front of a 22-inch screen at a distance of 70 cm. The Data Viewer program was used to process the eye movements. The parameters of gaze movements and the coefficients of reading techniques were compared using Spearman's correlation analysis. There was a correlation at different levels between the parameters of the oculomotor activity in children completing the task for the development of the angle of visual attention and the rank correlation analysis of indicators of reading skills in English. The study's point of view is the examination of the relationship between visual-spatial perception, the breadth of the angle of visual attention, and the functions of programming and control.

***Keywords:*** Reading Skills; English Text; Visual Attention.

## 1. Introduction

Reading units are recognized in both the parafoveal and foveal visual fields. Over the past few decades, experts have examined the connection between reading and parafoveal vision as research on the effects of previewing on the parafoveal expands our knowledge of English reading abilities. The reader's functional field is engaged by units situated in the parafovea. Prior research has determined that the adult normotypical reader's text perception area is restricted to a width of 3-5 characters to the left and 14–15 characters to the right of the fixation point (McConkie & Rayner, 1975). Furthermore, research has demonstrated a correlation between the degree of reading proficiency in English development among adult readers and the width of the visual attention angle, also known as the visual interval. The concept of widening the visual attention angle started to proliferate. There are now methods available that are based on activities designed to improve visual attention. The authors of these methods believe that consistent use of these exercises should improve reading speed and lead to the development of English reading skills. These strategies boil down to the reader fixing their gaze on a specific point and reading the units that are outside of their functional field without moving their eyes from the fixation point. The exercises' graphical representations are displayed as either numerical or alphabetic series with the fixation point in the center of the line, or as rectangular tables with numbers and letters.

Though these techniques are widely used in programs aimed at helping adults and children read more fluently in English, as well as in programs aimed at treating non-specific reading disorders like dyslexia, the characteristics of eye movement during exercises meant to increase the visual interval differ among readers with varying degrees of proficiency in the language. Meanwhile, the idea of expanding the angle of visual attention implies that measurements of the latitude of the visual interval in kids without reading problems exist; however, these measurements are not found in the scientific

literature. In the meantime, studies employing eye-tracking technologies can offer fresh information on the connection between reading strategies and the angle of visual attention in people with and without reading disorders. This information can be used to modify or expand upon strategies intended to increase or diversify the visual interval. The goal is to investigate the characteristics of oculomotor activity in children between the ages of 9 and 10 who have varying degrees of proficiency in reading English when it comes to identifying units situated in the parafovea and on the edge of the foveal region (Alekseeva et al., 2019).

## 2. Literature Review

As a crucial component of reading, the study of eye movements provides insight into the workings of the cognitive processes involved in reading. Cognitive functions are linked to the brain regions that control eye movements through neurons. Leigh and Zee (2015), oculomotor activity could be a useful neurophysiological indicator of their development. The fundamental elements of oculomotor activity in reading are saccades and fixations. Fixations are thought to be a reflection of how the brain processes visual information. Certain eye movement parameters, such as the amplitude and ratio of saccades that differ in direction, the duration of gaze fixation—which is influenced by the speed of lexical processing—the formation and retention in memory of the general meaning of the read material, and the programming of subsequent saccades, can also be linked to memorization of what has been read. Currently, it is understood that the number of regressive types of saccades decreases, their amplitude increases, and the average duration of fixations and number per word decrease as reading skills improve (Clifton et al., 2007).

Numerous studies' findings, including those derived from a meta-analysis involving over 160 investigations, attest to the critical role that the development of visual perception plays in the process of reading proficiency. The process of visual perception (VP) is intricate and challenging, involving multiple structural elements. Several authors claim that during the early phases of education, certain aspects of visual perception—like constancy, spatial orientation, visual–motor coordination, and noise immunity—become more prominent. Given that the majority of the literature currently in publication examines younger schoolchildren's struggles with reading formation in relation to the reading norm and the overall rate of visual perception development, information regarding the absence of individual VP component formation as potential neuropsychological predictors of reading difficulties, as well as details regarding the features of oculomotor activity in children with varying reading proficiency, is lacking (Bezrukikha et al., 2019).

## 3. Methodology

49 children with diagnosed visual and auditory analyzer disorders as well as those without neurological disorders were included in the study. The informants were between the ages of 9 and 10. The Standardized Method for Studying Reading Skills in English was used to evaluate students' English reading comprehension. Non-verbal intelligence was evaluated using the colored progressive matrices developed by Raven et al. (2012) and Alekseeva & Slyusar (2017). Using an exercise designed to improve the angle of visual attention, we also observed the informants' eye movements while they worked (Alekseeva et al., 2019). We used a numerical series with two rows of randomly generated single-digit numbers uniformly diverging from top to bottom and a series of consecutive numbers in the middle as the stimulus material that was shown on the screen. The side numbers in the numerical rows deviated by 1.6° to the right and left from the central number that was meant to be fixed in the first line.This angle of deviation increased by 0.45° in each subsequent line, until the side numbers in the stimulus material reached an angle of 9.7° to the right and left in the final line.

The informants' job was to focus on the numbers in the middle row and recognize the numbers on the left and right rows. The experiment was explained in detail to the participants, and after the calibration and validation steps were completed, the researchers were required to attend a training session. To ensure a more precise recording of all gaze movement parameters, the head was fixed using a tower. The Courier New monospace font, which has a point size of 26, was used to print the numbers in black on a white background. Although single-digit numbers rather than Cyrillic letters serve as important study fragments, monospace fonts perform worse than proportional fonts in terms of improving reader accuracy in unit recognition. Additionally, employing monospace allowed us to adjust the unit's pixel length. Since the use of symbols on both sides of the central key fragments helps to bring the experimental task closer to ordinary reading, the key fragments were presented with '...' symbols surrounding them. As per the testing methodology for determining operational reading units (Andreev & Khromov, 1991), single-digit numbers are the most automated reading units for all children with varying levels of English reading skills. This is why we used them in the experiment.

SR Research's Eye Link 1000+ equipment was used to record eye movements at a sampling rate of 1000 Hz. The informant was seated in front of a 22-inch screen at a distance of 70 cm. The Data Viewer program was used to process the eye movements. We used Spearman's correlation analysis to compare the coefficients of reading technique and some gaze movement parameters, such as the proportion of fixation duration on the region of interest, the total duration of gaze fixations on the peripheral rows with numbers located up to 7° from the fixation point inclusive and more than 7° from the fixation point, and the number of regressive saccades to a given central area.

## 4. Results

The reading technique coefficients of the children under study were ascertained based on the findings of the primary analysis. The diagnostic examination results showed that 12 out of 49 children had dyslexia symptoms: 26 out of 49 children had reading indicators at the average statistical norm; 11 out of 49 children had a non-pathological lag in the formation of English reading skills; and low coefficients of reading technique corresponding to dyslexia were observed with intact non-verbal intelligence, normal speech development, and the absence of auditory and visual perception disorders in children. Only in a few instances were there no fixations in either the left or right row of numbers, according to the primary analysis of the eye movements, indicating that none of the children were able to complete the task of uninterrupted gaze fixation solely on the central row of numbers. Simultaneously, every informant managed to identify the numbers on the left and right rows. The invisible border technique is frequently used in research on readers' perception of parafoveal units. In this technique, stimuli are presented to the left or right of the fixation center (i.e., to the left or right of the invisible border at a distance of 5 degrees of the visual angle); when the eye crosses the border, the stimulus vanishes (Deyue et al., 2010).

Subsequently, an analysis of Spearman's rank correlation was conducted. This method provides a statistical relationship between two variables, in this case, the reading technique coefficient and several eye movement parameters. The data were ranked, the share of the duration of gaze fixation on the aforementioned areas of interest was taken as the feature, and the coefficient of reading technique was taken as the correlation factor when performing a correlation analysis. Finding the correlation coefficient between the CRT and the percentage of gaze fixation duration in the central numerical series was the first step in the correlation analysis process. After the indicators were ranked, the ranks were reformed, which keeps the corresponding relationships between the rank numbers intact while not altering the rank's significance. The correlation analysis guidelines state that we cannot set the rank above or below a value equal to the number of parameters, in this case the 49 children that are the subject of the study. A rank matrix was created based on the reorganization of the ranks, and its accuracy can be verified by calculating the checksum using formula 1:

$$\Sigma x=(1+n)*n/2=(1+49)*49/2=1225 \quad (1)$$

The matrix is correctly composed because the sums over its columns equal each other and the checksum. In this instance, the Spearman coefficient is determined using formula 2 since there are multiple identical values among the indicators of the share of the gaze fixation duration in the central numerical series and CRT, forming bound ranks.

$$p = 1 – (\Sigma 6d^2 + A + B) / (n^3 – n) \quad (2),$$

where $A = 1/12\Sigma (A_j^3 – A_j)$

$B = 1/12\Sigma (B_k^3 – B_k)$

j – numbers of links in order for the value of CRT;

Aj – is the number of ranks that are identical in the j-th bundle based on the CRT value;

k – number of links required to display the percentage of gaze fixation duration in the main numerical series;

Bk – number of ranks that are identical in the k bundle according to the central numerical series' proportion of gaze fixation duration.

$$A = [(33-3) + (23-2) + (23-2) + (83-8) + (23-2) + (33-3) + (53-5) + (53-5) + (23-2) + (23-2) + (33-3)]/12 = 70.5$$

$$D=A+B=70.5$$

Therefore, p = 1 – (6*11788,5 + 70,5)/ ($49^3$ – 49) = 0,398. Weakly and directly, the sign (the percentage of gaze fixation duration in the central numerical series) and the factor (CRT) are related. Student's t-test comparisons were used to ascertain the significance of Spearman's rank correlation, as per formula 3:

$T_{kp} = t(a, k) * \sqrt{(1 - p^2)/(n - 2)}$ (3),

where n is the sample size, which in this instance is the total number of kids examined;

Spearman's rank correlation coefficient (p) is represented by the following: t (α, k) is the critical point of the two-sided critical region. This can be found using the Student's distribution critical point table, which takes into account the number of degrees of freedom (k) and the significance level (α), which is equal to the sample size (n–2). In this instance, the crucial element is t (α/2, k) = (0.05/2;47) = 2.311.

Therefore, $T_{kp} = 2{,}311 * \sqrt{(1 - 0{,}398^2)/(49 - 2)} = 0{,}31$.

Since $T_{kp} < p$, the assumption that the Spearman rank correlation coefficient equals zero is rejected. Stated differently, both the rank correlation coefficient and the rank correlation between the feature and the factor are statistically significant. While children with lower reading skill levels in English formation fix their gaze less in the center, higher reading skill levels in English formation have a higher proportion of gaze fixation duration in a given central area. This finding is consistent with a number of international studies and suggests that children with low English reading proficiency have a limited visual interval (Kuznetsov, 1998). The task of conscious inhibition of saccades, in which control functions play a role, should be considered, though, as it may account for children with low levels of English reading proficiency's lower level of visual attention concentration at a particular fixation point. Finding the correlation coefficient between the CRT and the quantity of regression eye movements in the area of the central numerical series was the second step in the correlation analysis process. We determined the Spearman's rank correlation coefficient (p = –0.361) between the trait and the factor (CRT) using the above scheme.

As a result, there is a weak and inverse rank correlation between the two indicators, and the rank correlation coefficient is statistically significant. Compared to children with more developed English reading skills, those with less developed reading skills made more regressive saccades to the stimulus material's center. The third step of the correlation analysis involved calculating the correlation coefficient, or p = -0.535, between the CRT and the total duration of fixations in the areas of interest of the central and peripheral numerical series. It's interesting that there is a moderate and inverse rank correlation between the two indicators, and the rank correlation coefficient is statistically significant.

## 5. Discussion

Children's reading speeds determine how much CRT they receive, but the analysis revealed that the indicators of text decoding skills increased with the total amount of time spent staring at the central and peripheral numerical series' areas of interest. This paradox can be explained by the following two facts: (1) the stimulus material employed the most automated operational units of reading; and (2) regulatory or control functions can be crucial in the early stages of reading development (Korinth et al., 2020). The duration of gaze fixation on number series whose peripheral area is up to 7.2° from the given fixation point, inclusive, and the duration of gaze fixation on number series whose peripheral area is more than 7.2° from the given fixation point, where p = 0.606, were found to be statistically significantly correlated. The indicators have a moderately direct relationship: the length of recognizable units (in this case, single-digit numbers) is maintained, but the duration of fixations increases as the area around the peripheral reading unit expands. Therefore, research in the field of studying reader strategies using gaze tracking technologies confirms that the location of units from the center of the reader's functional field is important.

## 6. Conclusion

The percentage of gaze fixation in the central numerical series, the number of regressive eye movements in the central numerical series region, the total duration of fixations on the areas of interest of the central and peripheral numerical series, and the duration of gaze fixation on the numerical series, the peripheral region of which is within the average statistical limits of the fovea and parafovea, were among the indicators of reading skills level and parameters of the oculomotor activity in children completing the task for the development of the angle of visual attention revealed a correlation at different levels. The relationship between visual-spatial perception, the length of the angle of visual attention, and programming and control functions must be investigated. To find homogeneous groups of primary school-

aged readers, more cluster analysis is required. Additionally, a more thorough examination of the connection between reading strategies and oculomotor activity features is required when completing tasks involving the recognition of units situated on the boundary between the foveal and parafoveal areas.

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