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EFFECT OF VISUAL DYSFUNCTION ON READING PERFORMANCE IN CHILDREN: AN EXAMINATION OF MISTAKES, PRECISION, AND READING RATE

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ABSTRACT

Background: Reading development in children may be influenced by visual function. This study investigated the relationship between anomalous visual function (AVF) and reading performance in school-aged children, with a focus on identifying whether visual anomalies contribute to reading difficulties. Methods: A total of 672 children aged 6–11 years participated, including 110 children with AVF and 562 children with normal visual function (NVF). Visual assessments included autorefraction, visual acuity, ocular alignment, near point of convergence, accommodation, stereopsis, and vergence. Reading ability was evaluated using a 34-word verb list, assessing error count, reading accuracy (percentage correct), and reading speed (words per minute). Sociodemographic information was collected from 670 parents and 34 teachers. Results: Children with AVF made more reading errors (3.00 vs. 1.00; $p < 0.001$), had lower accuracy (91.18% vs. 97.06%), and read more slowly (24.71 wpm vs. 27.39 wpm; $p = 0.007$) compared to NVF children. However, in third grade, reading speed differences between AVF and NVF groups were not statistically significant (31.41 wpm vs. 32.54 wpm; $p = 0.113$). Children with uncorrected hyperopia and astigmatism performed significantly worse on reading tests ($p = 0.003$). Reading difficulties were more prevalent in first-grade students and diminished in higher grades. Conclusion: Anomalous visual function is associated with reduced reading performance in early primary school children, especially in first grade. Visual anomalies, such as uncorrected hyperopia and astigmatism, may mimic dyslexia symptoms. Early visual screening is recommended to differentiate visual deficits from learning disorders and to provide timely interventions.

INTRODUCTION

Reading is a complex cognitive activity that requires the integration of both visual and phonological information, often prompting diverse interpretations and debates regarding the underlying processes. In today's visually demanding society, the ability to perceive single, clear images is fundamental for the efficient operation of the visuo-cognitive system involved in reading [1].

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Critical visual functions such as saccadic eye movements, convergence, fusion, accommodation, and refractive control are orchestrated by the visual cortex during reading tasks. These functions work in tandem with linguistic repetition, language processing, and cognitive assimilation—each playing a pivotal role in the acquisition of reading skills.

Reading, therefore, is not merely a linguistic task but a synergistic blend of verbal processing and visuomotor coordination, all directed toward achieving fluency and precision in interpretation [3]. It has been postulated that misconceptions surrounding the visual demands of reading have contributed to misinterpretations of reading difficulties [4]. Evidence indicates that deficits in either phonemic decoding or visual processing can independently hinder a child's reading proficiency [5]. In addition to neurological conditions such as dyslexia and limitations in intellectual functioning, factors like binocular vision abnormalities and speech articulation issues, along with social, familial, and economic contexts, have been associated with lower academic success and limited educational progression.

Interestingly, previous research suggests that abnormal visual function does not always show a significant correlation with academic or reading performance. Contradictorily, some studies propose that children with typical vision, but without cognitive or speech challenges, may still experience educational disadvantages in comparison to their visually impaired peers [2,5,7,9–13]. Other investigations further support the claim that visual capacity alone is not a strong predictor of academic achievement [14].

Objectives of the Study:

1. To compare reading performance—including error frequency, accuracy, and fluency—between children with normal and abnormal visual function.
2. To analyse differences in readability across school grades based on specific visual anomalies and refractive errors.
3. To evaluate the influence of abnormal visual function on reading ability while considering additional variables such as instructional strategies and parental educational background.

METHODS AND MATERIALS

In 11 mainstream schools, there are Portuguese primary schools were included in a cross-sectional study conducted in 2012. Six hundred and seventy-two typically developing children of Portuguese origin (6-11 years old) were sampled. Disabled children, those with neurocognitive disabilities, dyslexic children, and those with speech or language disorders were excluded. In addition to this, a questionnaire was sent out to 670 parents and 34 teachers to collect information about the teaching method, the academic qualifications of the parents, the kind of school (public or private), the age of the teacher and the number of years they've worked at the school, and also the grade of the child.

The Declaration of Helsinki was adhered to in this study. The National School of Public Health in Lisbon provided ethics approval for the study. The study was explained to all selected school administrators and they agreed to participate. To include a child's data in the study, informed consent was obtained from the parents. It was guaranteed that the information given would remain confidential. Orthoptists performed orthoptic assessments and autorefractions on all children:

A Sure Sight TM Welch Allyn® autorefractometer was used to screen for refractive error. Astigmatism and anisometropia were classified as two types of refractive errors, respectively: hyperopia and myopia [15].

Good-Lite® charts with Sloan letters serially spaced at 3 meters, as well as Good-Lite® charts with LogMar letters serially spaced at 40 cm, were used to measure distance and near visual acuity. The last line of the test requires that at least three of the five letters are correctly identified. Visual acuity was considered abnormal (near but not distance) if there was no difference between the two eyes in visual acuity. A decimal number was converted to a logarithmic value using decimal notation [19]

Cover tests (CT) were performed at 6 meters and 33 cm from the eyes to detect heterotropias and heterophorias. A black paddle occluder was used as a cover during the CT scan. As targets, we used detailed fixation objects. As defined by [20], manifest strabismus is any degree of tropia at a distance or near fixation [21]. The magnitude of the deviation was assessed by a prism cover test.

Royal Air Force (RAF) rules were used to assess near point of convergence (NPC). Three measurements were taken and the mean was recorded in cm. When the NPC exceeds 10 cm, it is considered abnormal [21]. A RAF rule was used to assess NPAs. A diopter measurement was taken based on three measurements. As of 14.00D [22], NPAs were considered abnormal. The Stereo Butterfly SO-005 test was used to assess stereoacuity at 40 cm, and abnormal measurements were recorded when the distance exceeded 60" [23].

The head was held straight at 6 m and 33 cm for the assessment of vergences (motor fusion). The targets were detailed fixation objects. With the help of prisms, we assessed motor fusion. The NPC > 10 cm requirement for a convergence insufficiency classification is combined with either the 18PD, the 12PD, or the 6PD criteria With a pen light, nine cardinal positions were measured for eye movement (versions and ductions). As long as the orthoptic assessment and autorefraction results were normal, The vision function of children was considered normal. If glasses were previously prescribed, they were examined with optical correction. If abnormal visual functions were detected in children without prescribed glasses, they were referred to an ophthalmologist for further medical treatment.

With a list of 34 Portuguese words that have previously been used for reading assessment, error rates, accuracy, and reading speed were assessed [24]. A TES-1330 luximeter was used to measure room illumination for both groups of subjects in a quiet room. A distance of 40 cm was assigned to each child so they could read the 34 words. There was a restriction on how close the children could get to the page. Time was measured with a stopwatch as the task was completed. wpm (words read per minute) is the child's reading speed. This equation was used to calculate accuracy (A) based on the number of incorrect words read:

There are two types of words read: NCW and WR. It is based on three levels of performance, which have been published and validated [26]. The first level is independent reading (accuracy between 96% and 100%); the second level is instructional reading (accuracy between 90-95%); and the third level is frustration reading (accuracy between 90-95%).

Continuous variables were tested by Mann-Whitney, and continuous variables for more than three groups were tested by Kruskal-Wallis. P values less than or equal to 0.05 or 0.01 were considered statistically significant. In addition, we used a binary logistic regression technique to identify risk factors for failing to read well. Several variables were selected for inclusion in the model by following a step-by-step approach (conditional). A 5% significance level was used in the Wald test to test the significance of the parameters [27,28].

RESULTS

One hundred and forty-two children have deficient vision (or 16.4%), while 562 have normal vision (mean age, 7.68 ± 1.19 years). The gender and age of the two groups did not differ significantly (p=0.675). Similarly, the degree of illumination, parents' educational qualifications, and professors' years of teaching experience did not differ between comparison groups (p=0.987). Similar teaching methods were used by both groups.

There were 110 children who had One hundred and seventy-seven percent of those, 17 of whom were manifest strabismus, 66 were unable to see distance objects at 0.1 logMAR, two were suffering from convergence insufficiency, and fifteen demonstrated stereoacuity above 60", while the remaining 10 had manifest strabismus as well as a visual acuity below 0.1 logMAR at distance. Of the children identified with strabismus 4 had an uncorrected refractive error. Of the children with visual acuity ≥0.1 logMAR at distance 15 had an uncorrected refractive error, mainly hyperopia (10.6%) and astigmatism (9.1%). Acuity for near and distance was abnormal in only two children. [29]

A total of 11 children with manifest strabismus have stereoacuities greater than 60" Approximately 400 inches (median). Additionally, two children had uncorrected refractive errors among the 17 children whose stereoacuity was >60" (median=80"). with a stereoacuity >60" (median=40") with strabismus.

Ability to read

In the abnormal visual function group, errors increased from 3 to 1 (AVF3.00; NVF1.00; p0.001), accuracy decreased from 91.18% to 97.06%, and reading speed decreased from 24 to 27 in the abnormal visual function group (AVF24.71; NVF27.39; p0.007). In a study of children with abnormal visual functions, 18.9% were accurate, while 40% were incorrect.

Additionally, we compared the reading performances of children in first through fourth grades. It was statistically significant that the percentage of errors and accuracy varied from group to group per grade with subjects with abnormal vision having a higher percentage of errors. There was no This was the only grade where reading speed did not differ statistically between groups (AVF=31.41wpm; NVF=32.54wpm; p=0.113).

According to Table 2, reading performance for individuals who have uncorrected refractive error and abnormal visual function is shown. Reading speed was fastest among children with visual acuities less than 0.1 logMAR. The average reading speed of children with strabismus at 0.1 logMAR versus children with strabismus and normal visual acuity was 26.34 wpm, which is lower than that of children with strabismus at 30.94 wpm. There were no significant differences between the groups in accuracy or reading speed (errors=0.994; accuracy=0.922; speed=0.652), despite all groups having nonsignificant differences in reading performance (errors=0.994; accuracy=0.922; speed=0.652).

In comparison to children without or corrected refractive errors, children with uncorrected hyperopia scored lower on A reading speed of 16.20 words per minute and accuracy of 88.24% are among the findings (Table 2). Uncorrected hyperopia was significantly different from uncorrected astigmatism, as was uncorrected hyperopia from children without refractive errors (p=0.003).

Additionally, we compared children's refractive status scores (0.50D, 1.00D, 2.00D and >2.00D) and spherical refractive status scores (1.00D, 2.00D, 3.00D, and >3.00D). The reading speed of students with spherical refractive scores greater than 24.25 wpm was significantly lower, with a median value of 3.00, a lower accuracy score of 91.18 percent, and higher errors (median of 3.00). When cylindrical refractive scores were above 2.00D, children had slower reading speeds (18.42 words per minute). Both children without and with corrected refractive errors showed no significant differences.

Children's reading performance was assessed by direct logistic regression by assessing seven factors: their visual function (normal/abnormal), the method of teaching, the academic qualifications of their parents, the type of school they attended, their age, their career years, and their grade. If the accuracy of your reading is less than 90%, you are considered to have a low reading performance. [26].

Based on the full logistic regression model, the likelihood of a low reading performance was significantly different from the likelihood of a low reading performance for non-low-performing children. A 39.3% sensitivity and 94.3% specificity were calculated for the model. 67.1% of the samples were positive, whereas 84.0% were negative. Statistically significant risk factors or predictors were identified at the An OR of 4.29 was found, with a 95% confidence interval of 2.49 to 7.38 (OR = 4.29, C.I. 95% (2.49; 7.38)). A child with a visual function anomaly is more likely to have a low reading performance. There was, however, a protective factor associated with children's grade (p0.001): [OR 2nd=0.17; C.I. 95% (0.09; 0.29); OR 3rd=0.08; C.I. 95% (0.04; 0.16); OR 4th=0.04; C.I. 95% (0.02; 0.09)]. Compared to the 1st grade, students in the 2nd, 3rd, and 4th grades were less likely to have low reading performance. In our model of reading performance, we examined the variables teaching methodology, parental academic credentials, school type (public versus private), teacher age, teacher experience, and child grade

Table 1: Grades and groups of children's reading performance.

Ability to read	**An average minus a standard deviation**		**Median Average**		**Value P**
	NVF+	AVF++	NVF+	AVF++	
Error rate	2.20 ± 3.24	4.40 ± 5.54	1.00	3.00	<0.001*
First	3.99 ± 4.36	11.10 ± 8.07	2.00	9.00	<0.001*
Grade-level errors					
Second	1.67 ± 1.88	4.26 ± 4.78	1.11	3.00	<0.002*
Third	1.27 ± 1.74	2.53 ± 3.11	1.11	2.00	0.004*
Fourth	1.17 ± 1.54	2.08 ± 2.74	1.11	1.00	0.035**
Inaccuracy (%)	91.05± 16.95	80.88 ± 26.33	97.14	91.36	<0.002*
Percentage accuracy					
First	78.71 ± 27.94	53.19 ± 29.25	91.18	60.29	<0.002*
Second	93.97 ± 9.65	83.48 ± 21.44	97.06	91.96	<0.002*
Third	95.32 ± 6.44	88.87 ± 22.32	97.06	94.36	0.001*
Fourth	95.46 ± 8.99	93.99 ± 5.44	97.06	94.25	0.036**
In words per minute, what is your reading speed?	28.47 ± 16.66	23.02 ± 15.25	27.39	24.69	0.007*
Graduation rate for reading					
First	13.87 ± 9.77	5.02 ± 5.14	12.77	3.36	<0.001*
Second	25.15 ± 12.99	17.45 ± 11.21	24.54	16.98	<0.001*
Third	34.19 ± 11.55	29.96 ± 12.36	32.25	31.36	0.113
Fourth	41.94 ± 14.77	38.21 ± 16.47	40.11	35.87	0.031**

Table 2: Uncorrected refractive errors and anomalies in the visual function affect reading performance.

Anomalies with the visual system	**Ability to read**	**Standard deviation + mean**	**Indicator**
As a result of 0.1 logMAR (n=66), visual acuity was measured.	Mistakes	4.63 ± 5.99	3.11
	Reliability	81.46 ± 24.57	91.26
	Time it takes to read	21.94 ± 15.55	20.47
A total of 17 people were diagnosed with strabismus	Inaccuracies	4.25 ± 5.47	1.36
	Efficacy	82.35 ± 26.23	94.36
	Time it takes to read	26.25 ± 16.77	30.47
Acute visual acuity combined with strabismus, ≥0.1 logMAR (n=10)	Anomalies	5.00 ± 7.52	3.11
	Reliability	68.82 ± 40.32	91.36
	Time it takes to read	20.71 ± 14.47	26.34
(n=2) Insufficiency of convergence	Inaccuracies	3.00 ± 0.00	3.14
	Reliability	91.18 ± 0.00	91.36
	Time it takes to read	29.30 ± 0.22	29.30
(n=15) Stereoacuity >60"	Mistakes	3.64 ± 3.36	3.00
	Efficacy	83.33 ± 24.41	91.18
	Time it takes to read	24.85 ± 16.36	23.86
Visually normal children	Mistakes	2.20 ± 3.14	1.00

	Reliability	91.05 ± 16.98	97.06
	Time it takes to read	28.32 ± 16.47	27.39
A non-corrected optical error	Ability to read	Mean ± Standard deviation	Median
(n=11) Hyperopia	Mistakes	5.11 ± 5.44	3.11
	Reliability	70.32 ± 35.69	88.32
	Time it takes to read	16.18 ± 12.88	16.52
Instability (n=9)	Mistakes	4.75 ± 5.87	2.11
	Reliability	71.57 ± 33.98	91.24
	Time it takes to read	19.34 ± 17.25	20.66
(n=5) Anisohyperopia	Mistakes	2.40 ± 2.87	2.00
	Reliability	92.94 ± 7.98	94.23
	Time it takes to read	30.42 ± 12.87	26.64

DISCUSSION

To better understand how visual function anomalies affect reading abilities in children, this study examined Anomalies of visual function in children who read. It is clear from the results that this population is afflicted with different levels of visual function, which may have a direct influence on reading skills.

A significant difference in reading performance was found between children with and without visual function anomalies. A visual anomaly may impede the development of reading skills and highlight the critical role that vision plays in reading acquisition. [30]

The disruption of visual perception could explain the observed connection between visual function anomalies and reading difficulties. It can be difficult for children to perceive and process written text accurately if they have visual anomalies, such as refractive errors, strabismus, or amblyopia. A person may have difficulty recognizing letters, decoding words, and reading fluently as a result.

Additionally, visual anomalies can interfere with eye movements and scanning patterns during reading. An atypical eye movement pattern is present in children with anomalies, including reduced fixation stability, shorter saccade lengths, and more regressions. When eye movement abnormalities are present, visual information cannot be processed and incorporated efficiently and fluently.

Additionally, reading comprehension processes may be affected by visual anomalies. Vision and eye movement difficulties may reduce engagement with texts, impair narrative structure tracking, and compromise content comprehension. Comprehending problems may arise even when basic decoding skills are intact due to these factors.

There are important clinical implications to be drawn from the findings of this study. For children to attain optimal reading outcomes, it is crucial that visual function anomalies are detected early and appropriately managed. The identification and treatment of visual anomalies that may affect reading development should be implemented through regular vision screenings and comprehensive eye examinations. Children with visual anomalies should be supported to achieve optimal reading skills by a multidisciplinary approach that involves prescription eyewear, vision therapy, and surgical interventions.

It may also be beneficial for children with visual anomalies to receive interventions that target both their visual function and reading skills. The performance of reading can be improved by vision therapy programs designed to improve eye movement, visual perception, and visual-motor integration. A comprehensive reading intervention program should also be implemented to facilitate the development of phonological awareness, decoding skills, and comprehension strategies.

The current study has some limitations that should be acknowledged. It may be difficult to generalize the results due to the limited sample size and the specific types of abnormalities that were examined. Researchers should investigate the relationship between specific visual function characteristics and reading abilities using larger and more diverse samples, taking into account a wider range of visual anomalies.

CONCLUSIONS

In order to maximize reading outcomes in children, it is crucial to detect visual function abnormalities early and manage them appropriately. To identify and correct visual anomalies that may impact reading development, regular vision screenings and comprehensive eye examinations should be implemented. In order to overcome visual obstacles to reading, children may need special eyeglasses, vision therapy, or surgical interventions.

Children with visual anomalies can benefit from interventions that target both their vision and their reading skills. Visual therapy programs can enhance reading performance by improving eye movements, vision perception, and visual-motor integration. Several evidence-based reading interventions should also be implemented to support reading development, including decoding skills, phonological awareness, and comprehension strategies.

The impact of visual function anomalies on reading performance requires further research. By using a larger and more diverse sample, a study can be made more generalizable. The longitudinal study of visual function anomalies can also provide insightful insights into how they affect reading skills and education as they mature.

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