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# The relation between the severity of reading disorder and visual functions among children with dyslexia

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## Abstract:

**PURPOSE:** The purpose of the study was to investigate the relation between the severity of reading disorder and visual functions among children with dyslexia.

**MATERIALS AND METHODS:** The present study included 32 dyslexic children selected from two centers for learning disabilities in Mashhad, Iran. Dyslexics were then classified as mild, moderate, and severe based on an instrument used to determine the severity of their reading disorder. Complete optometric examinations to measure visual acuity, refractive errors, latent and manifest deviations, stereoacuity, and amplitude of accommodation were performed for all participants. The correlation between visual functions among dyslexics and their reading disorder severity was investigated.

**RESULTS:** The mean age of the participants in this study was  $8.1 \pm 0.8$  years. Among participants, 40.6%, 31.3%, and 28.1% presented with severe, moderate, and mild levels of reading difficulties, respectively. Only exophoria significantly correlated with the severity of reading disorders. No significant correlation was found between other visual functions and the severity of reading disorders in dyslexic children.

**CONCLUSION:** We found that higher exophoria at near has a significant correlation with the severity of dyslexia. A complete and detailed eye examination of patients with dyslexia and correcting their visual impairments might be helpful.

## Keywords:

Children, dyslexia, severity, visual function

## Introduction

Dyslexia is a neurodevelopmental reading disability with negative effects on the speed and accuracy of word recognition which disrupts reading fluency and text comprehension and occurs in 5%–10% of the population.<sup>[1-4]</sup> Approximately 80% of individuals with learning disabilities suffer from dyslexia, which is why dyslexia is known to be the most prevalent learning disorder in young students.<sup>[5,6]</sup>

The mechanism of dyslexia is still controversial. Dyslexic people show average

intelligence, so their disability cannot be explained by lower intelligence.<sup>[7]</sup> In a common theory, phonological deficits constitute the main cause of dyslexia.<sup>[8-10]</sup> However, further studies have revealed that sensory and visual perceptual dysfunctions might play a role.<sup>[11]</sup> Fluent reading requires rapid processing of visual information, including spatial and temporal data.<sup>[12,13]</sup> It has been proposed that dyslexic children might have a deficit in rapid processing of visual and auditory modalities.<sup>[14]</sup> Principally, this hypothesis implies that deficits in phonological decoding found among dyslexics (such as pseudoword reading) can arise from damage to sensory processing

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of visual and auditory stimuli.<sup>[15-19]</sup> Furthermore, anatomical and psychophysical studies indicate that some dyslexic patients might experience decreased sensitivity to contrast, flicker, and/or motion.<sup>[20]</sup> Many previous studies have evaluated the role of vision in dyslexic patients. For example, Wahlberg-Ramsay *et al.*,<sup>[4]</sup> suggested that in dyslexic children reading problems are the result of phonological deficit among these patients and not an underlying cause of dyslexia. Binocular vision abnormalities in dyslexic children might be related to phonological deficits but not to visual problems. Dysli *et al.*<sup>[21]</sup> reported that phoria is of low importance in dyslexia and correcting small-angle heterophorias fails to help dyslexic children. Trauzettel-Klosinski *et al.*<sup>[22]</sup> documented that phonological difficulty had effects on reading speed and eye movement pattern; for instance, dyslexic children presented considerable increases in their number of eye movements. Motsch and Mühlendyck<sup>[23]</sup> highlighted the importance of the correction of even small refraction and/or motility errors when accompanying reading and writing difficulties. Kirkby *et al.*<sup>[24]</sup> demonstrated that if dyslexic individuals read sentences rather than scanning dot, the amplitude of fixation disparity would be on the rise, which might induce inappropriate binocular eye movements in these patients. Furthermore, a few attempts have been made to determine if contrast sensitivity (CS) affects the severity of reading disorders.<sup>[25,26]</sup>

The present study was performed to further assess the correlation between the severity of dyslexia and visual functions and find out which visual function deficit is more correlated with the severity of dyslexia.

## Patients and Methods

In the present study, 32 dyslexic patients were evaluated. They were recruited from two centers for learning disabilities in Mashhad, Iran. The exclusion criteria included significant systemic diseases, using contact lenses, or taking any systemic or ocular medications. In addition, patients with neurological, emotional, or behavioral disorders and any undesirable educational condition that could impede their school performance in reading, spelling, and Stanford–Binet IQ tests were excluded. The minimum score of IQ for study participants was 90 and those patients with lower IQ scores were excluded. The present study was approved by the Ethics Committee of Mashhad University of Medical Sciences (approval number: IR.MUMS.REC.1395.615) and written consent was obtained from parents before entering their children into the study.

To diagnose dyslexia among participants, a professional team of psychiatrists and speech therapists were employed. Moreover, the medical records of dyslexic children were reviewed in full. Then, they were

subjected to the Reliability and Validity of Reading and Dyslexia (NEMA) test, which is a reading and dyslexia test designed for Iranian population.<sup>[27]</sup> The standardized scores of NEMA test and scores in every subscale were compared to determine the severity of dyslexia among the patients. Using this method, we divided the patients into mild, moderate, and severe dyslexia.

Subsequently, an E Snellen chart at 6 m was employed to evaluate monocular visual acuity, while the optimal optical correction was carried out. The objective examination of refractive errors was performed using the Heine BETA 200 retinoscope (Germany). The subjective measurement was conducted applying a trial frame and lens set under binocular and monocular conditions. Amplitude of accommodation (AA) and near point accommodation were calculated in centimeter and diopter, respectively, by a target chart (where the 20/20 line of letters was close) approaching toward the individual until the point of blur was detected (the push-up method). The test was performed for each eye and both eyes together among all the participants. Since the mean values were close to each other, only the results for both eyes were used in final comparisons. The TNO Stereoacuity Test (Lameris Ootech, Ede, The Netherlands) was employed to evaluate the degree of stereopsis. In order to investigate the prevalence of heterotropia and heterophoria, a cover test was conducted at near and far fixations (40 cm and 6 m). During the test, a letter in the line above the line with poor VA was used as a far target, whereas a letter of a size equivalent to 6/15 acted as a near target. Furthermore, the correlation between the severity of reading disorders and all visual functions was determined in the dyslexic group.

The CS assessment was conducted using the Cambridge low-contrast grating test (Clement Clarke, London, UK) at a spatial frequency of 4 cpd, equal to visual acuity of 20/150. Measurements were conducted for each eye separately and also both eyes together (binocular testing). The test had 12 pairs of plates with a luminance of 150 cd/m<sup>2</sup>. The presentation of plate pairs was in descending contrast, and each eye was tested by a forced-choice procedure four times. The observer was asked to choose if the top or bottom plate had the grating target. Thereafter, the number of pages for which an error occurred was counted. A conversion table was utilized to record the final score of CS.

All examinations were conducted by the same trained examiner under identical environmental conditions.

## NEMA test

At enrollment, dyslexia was diagnosed based on NEMA test, which consists of two main parts: the first part contains vocabulary tests with high-frequency

and medium-frequency words, word comprehension, elimination of sounds, and reading pseudowords and nonwords, whereas the second part has a chain of words, rhymes, identifying pictures series 1 and 2 of things, and comprehension of text and signs. We used five subscales of NEMA test including reading words (three lists of low-, moderate-, high-frequency words), text reading comprehension (a common text for all grades and two different texts for each grade), word comprehension, reading nonwords (nonsense words), and word chains. This test has been validated by Moradi *et al.*,<sup>[27]</sup> with a Cronbach's alpha of 0.48–0.98 for the subtests used in the present study.

### Statistical analysis

SPSS software version 16 (IBM, Armonk, NY, USA) was used for statistical analysis and Pearson or Spearman correlation tests were applied based on normal or abnormal distribution of data, respectively. Repeated-measures ANOVA was used to determine whether there are any significant differences between the means. Furthermore, the relation between near and distance phoria and the severity of dyslexia were calculated using Chi-square test.  $P < 0.05$  was considered statistically significant.

## Results

In the present study, of 32 participants, 17 patients (53.1%) were male and 15 patients (46.9%) were female. The average age of the patients was  $8.1 \pm 0.8$  years [Table 1]. In descending order, 40.6% ( $n = 13$ ), 31.3% ( $n = 10$ ), and 28.1% ( $n = 9$ ) of the dyslexic children experienced severe, moderate, and mild levels of reading disorders, respectively [Table 1]. Of all patients, 21.9% were in first elementary school grade, 62.5% in second grade, 9.4% in third grade, and 6.2% in fourth grade. The mean refractive error as spherical equivalent was  $0.07 \pm 0.77$  for the right eye and  $0.064 \pm 0.69$  for the left eye.

As presented in Table 2, refractive errors (sphere, cylinder, spherical equivalent, hyperopia, and myopia) in both left and right eyes were not significantly correlated to the severity of reading disorder. In addition, no significant correlation was found between the severity of reading disorders and VA in either left ( $P = 0.56$ ), right ( $P = 0.54$ ) or both eyes ( $P = 0.54$ ).

The relation between near and distance phoria and the severity of dyslexia is presented in Table 3. There was a statistically significant relation between near exophoria and the severity of dyslexia ( $P = 0.004$ ). There was no significant association between AA ( $P = 0.934$ ), near point of accommodation ( $P = 0.956$ ), and degree of stereopsis ( $P = 0.998$ ), with the severity of reading disorders [Table 4].

**Table 1: Demographic findings of patients entering the study**

Variable	Findings
Age, mean±SD	8.06±0.8
Spherical equivalent, mean±SD	
Right eye	0.07±0.77
Left eye	0.064±0.69
Visual acuity – LogMAR, mean±SD	
Right eye	0.002±0.011
Left eye	0.004±0.018
Both eyes	0.002±0.011
Gender, <i>n</i> (%)	
Male	17 (53.1)
Female	15 (46.9)
Severity of dyslexia, <i>n</i> (%)	
Mild	9 (28.1)
Moderate	10 (31.3)
Severe	13 (40.6)
Elementary school grade, <i>n</i> (%)	
First	7 (21.9)
Second	20 (62.5)
Third	3 (9.4)
Fourth	2 (6.2)
Total cases	32 (100.0)

SD=Standard deviation

The severity of reading disorders was not correlated with the mean value of CS for the right eye, left eye, and both eyes [Table 4].

## Discussion

This study was intended to explore the relationship between the severity of reading disorders and visual acuity findings in dyslexic children. Despite a large number of studies regarding dyslexia, few studies have investigated the severity of reading disorders in these patients. Previously, it has been indicated that children with learning disabilities, such as dyslexia, are more likely to experience disorders of visual function, and reading difficulties are usually associated with these disorders, namely binocular vision abnormalities.<sup>[28,29]</sup> A descriptive study reviewing 114 articles published between 2000 and 2012 showed that eye movement anomalies, pseudo neglect, and visual contrast deficits constituted the most important ophthalmic properties ascribed to dyslexia.<sup>[30]</sup>

In the present study, the majority of the dyslexic children (62.5%) were in the second grade. This observation may imply that the second grade children face great challenges in reading. Indeed, first-grade children usually learn letters, basic words, and short sentences. When they have problems during reading tasks, teachers and parents provide them with enough opportunities to repeat and practice more than once and never think about dyslexia after they see these problems.

**Table 2: The relation between sphere, cylinder, spherical equivalent, visual acuity, and myopic or hyperopic stage with the severity of dyslexia**

Description	Severity			P*
	Mild	Moderate	Severe	
Sphere, mean±SD				
Right eye	0.55±0.86	0.77±0.52	0.57±0.46	0.97
Left eye	0.41±0.43	0.88±0.78	0.86±0.83	0.54
Cylinder, mean±SD				
Right eye	-0.8±1.3	-0.69±0.54	-0.86±1.04	0.54
Left eye	-0.69±0.99	-0.77±0.7	-0.75±1.13	0.86
Spherical equivalent, mean±SD				
Right eye	0.13±0.39	0.41±0.375	-0.21±1.05	0.84
Left eye	-0.05±0.2	0.38±0.53	-0.076±0.93	0.63
Visual acuity, mean±SD				
Right eye	0±0	0.0046±0.01	0.003±0.012	0.54
Left eye	0±0	0.0097±0.03	0.003±0.012	0.56
Both	0±0	0.0046±0.01	0.003±0.012	0.54
Hyperopic or myopic stage				
Right eye, n (%)				
Hyperopia	8 (88.9)	9 (90.0)	11 (84.6)	0.74
Myopia	1 (11.1)	1 (10.0)	2 (15.4)	
Left eye, n (%)				
Hyperopia	8 (88.9)	9 (90.0)	11 (84.6)	0.74
Myopia	1 (11.1)	1 (10.0)	2 (15.4)	

\*ANOVA test. SD=Standard deviation

**Table 3: The relation between near and distance phoria and the severity of dyslexia**

Description	Severity			P*
	Mild	Moderate	Severe	
Distance cover				
Exotropia	0	1	1	0.642
Exophoria	1	0	2	0.445
Esophoria	0	0	1	0.47
Orthophoria	8	9	9	0.353
Total	9	10	13	0.65
Near cover				
Exotropia	0	1	0	0.321
Exophoria	2	6	12	0.004
Esophoria	2	2	1	0.588
Orthophoria	5	1	0	0.003
Total	9	9	13	0.007

\*Chi-square test

As school grade level increases, these dyslexic children become withdrawn and isolated due to a notable contrast between their reading skills and those of their peers.

The present study showed that 40.6%, 31.3%, and 28.1% of the dyslexic children presented with severe, moderate, and mild levels of dyslexia, respectively. Creavin *et al.*<sup>[30]</sup> have reported that only 3% of their patients showed severe dyslexia. Furthermore, another study in the US

found that the majority of children with dyslexia had a mild level of dyslexia, and only very few showed severe levels.<sup>[31]</sup> It should be noted that the levels of dyslexia are defined by different methods in different studies. Therefore, the results could not be compared directly.

Furthermore, the difference may be explained with the design of the present study that was a nonrandomized observational analysis of patients known to have dyslexia, whereas others recruited their participants from normal schools by a screening process. Moreover, it is likely that a difference in health-care levels can cause this difference in such a way that developed countries pay more attention to early diagnosis of learning disabilities, even at mild levels, through screening processes, which, in turn, prohibits their progression.

In the present study, visual acuity, refractive errors, and stereo acuity had no connection with the severity of this disease. Similarly, Creavin *et al.*<sup>[30]</sup> observed no association between the severity of reading impairment and strabismus, refractive errors, accommodation, and stereo acuity.

The results of the present study indicated that exophoria at near had a significant correlation with the severity of dyslexia. In addition to phoneme processing disorders in dyslexic children, ocular motor disorders, such as phoria, may cause reading difficulties. While reading, the angle of vergence of the optic axes should be continued. Dyslexics fail to maintain the angle of vergence. Ocular motor disorders may induce fixation instability and ultimately disruption of fusional process and complicated recognition of letters or words.<sup>[32]</sup> Pan *et al.*<sup>[33]</sup> found that dyslexics displayed more and longer fixations than control peers. An elevation in the reading time of words for dyslexic children arose from the increased number of fixations and duration of viewing.

We observed that the severity of dyslexia had no correlation with CS. This finding was not in line with the previous reports, which have emphasized the presence of a CS deficit in dyslexic individuals.<sup>[11,34-38]</sup> It has been suggested that the major cause of visual deficits in dyslexia is changed in CS.<sup>[39]</sup> Lovegrove *et al.*<sup>[36]</sup> investigated CS in dyslexics and controls at spatial frequencies of 2, 4, 12, and 16 cpd using nine stimuli with different durations. They reported that dyslexics were less sensitive than controls. This reduction was greater at a spatial frequency of 4 cpd.<sup>[36]</sup> In addition, Atkinson<sup>[40]</sup> used the Pelli-Robson CS chart to measure CS in both dyslexic and control groups. It was shown that there was a sensitivity decline in dyslexic individuals during monocular vision but a normal CS compared to the controls with binocular vision.<sup>[40]</sup> However, our results were consistent with several other studies, which have found no relationship between

**Table 4: The relation between amplitude of accommodation, near point of accommodation, and contrast sensitivity with the severity of dyslexia**

Description	Severity (mean±SD)			P*	Correlation coefficient	P (correlation coefficient)**
	Mild	Moderate	Severe			
Amplitude of accommodation	0.082±0.023	0.098±0.026	0.08±0.013	0.135	0.015	0.934
Degree of stereopsis	138.33±100.56	57±9.48	106.15±78.05	0.065	0	0.998
Near point of accommodation	13.22±3.49	10.9±2.96	12.76±2.385	0.186	0.010	0.956
Contrast sensitivity						
Right eye	102.6±48.18	130.1±57.3	122.53±27.11	0.393	0.271	0.134
Left eye	96.33±39.43	126±47.95	112.69±26.44	0.249	0.222	0.223
Mean	99.5±43.6	128.05±51.25	117.61±26.29	0.313	0.240	0.177

\*ANOVA test, \*\*Spearman's Rho. SD=Standard deviation

dyslexia and CS.<sup>[20,38]</sup> For example, Williams *et al.*<sup>[41]</sup> found no significant difference in CS between dyslexic and control groups in response to either stimulus. In addition, Creavin *et al.*<sup>[30]</sup> failed to show any relationship between the severity of reading disorders and CS.

## Conclusion

We found that higher exophoria at near has a significant correlation with the severity of dyslexia. A complete and detailed eye examination of patients with dyslexia and correcting the patients' visual impairments might help in treatment of these patients.

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## Conflicts of interest

The authors declare that there are no conflicts of interest of this paper.

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