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Review Article

Accommodation and vergence functions among children with dyslexia: A review of literature

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ABSTRACT

Based on a qualitative study of a broad and varied body of literature, this review of literature reveals the potential roles of accommodation and vergence in children with dyslexia. With a thorough literature study, this review of literature aims to provide an all-encompassing perspective on the binocular vision parameters in children with dyslexia and its significance in clinical practice in this review, addressing the lack of a comprehensive study in this area. By summarizing the latest research, this article is a valuable resource for researchers, clinicians, educators, and individuals interested in comprehending the relationship between dyslexia and binocular vision and exploring potential connections and implications. Both original and review papers were examined by searching research databases from 1991 to 2022, including PubMed, Google Scholar, and Ovid. The ROBINS-I risk of bias assessment approach for non-randomized trials was used to evaluate the quality of the included papers. This review includes a total of eighteen articles. Because only the dyslexic population was studied in this study, all of the studies were non-randomized. Changes in Ocular parameters, the function of Accommodation, and Vergence in the dyslexic population were observed and included in this study. This review of literature provides educators and clinicians with crucial insights and awareness to enhance their understanding of the parameters associated with non-strabismic binocular vision disorders in children with dyslexia, as well as strategies for detection. Evidence-based guidelines can be created for controlling and assessing binocular vision parameters in children with dyslexia and their importance in clinical practice.

1. Introduction

Dyslexia is a learning disorder that affects reading, writing, and spelling skills. It is estimated to affect around 5 to 10% of the population and often runs in families. Dyslexia is a neurological condition affecting how the brain processes written language. On the other hand, binocular vision refers to using both eyes in coordination to form a single, three-dimensional image. It is an essential aspect of visual perception, and it helps us to perceive depth and distance accurately.[1] Itaffects many factors, including eye movements, eye alignment, and the ability of the brain to fuse images from both eyes into a single, coherent picture.[2]

Research has shown that there may be a connection between dyslexia and binocular vision problems. Research suggests that people with dyslexia may also struggle with binocular vision, such as eye tracking, eye teaming, and convergence.[3] These difficulties may contribute to

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the reading difficulties experienced by individuals with dyslexia. However, the association between dyslexia and binocular vision problems is complex, and significant research is required to understand it fully.[4] Some researchers have suggested that binocular vision problems may be a consequence of dyslexia rather than a cause. In contrast, others have proposed that underlying neurological factors may cause both conditions.[5] Despite the lack of consensus, it is clear that addressing binocular vision problems can improve reading performance in some individuals with dyslexia, and this area continues to be an active area of review of literature interest.

1.1. Accommodation & vergence function in children with dyslexia

Inspected investigations revealed poor monocular accommodative amplitudes and the binocular accommodative capability, which is optical power it can achieve by changing its focus. Low Negative relative accommodation (NRA) and positive relative accommodation (PRA), where NRA Measures the most outstanding accommodation relaxing capacity while preserving unobstructed, single-binocular vision and PRA Measures the most remarkable accommodation-stimulating capacity while preserving clear, single-binocular vision values, which are categorized as accommodative insufficiency which in turn results in asthenopic symptoms. Symptom reduction and improved focus may be achieved with therapy, including lens adjustments and accommodative training.[6,7] Decreased vergence reserve amplitude at near, demonstrating reduced distance base-in (NFV) vergence, inadequate vergence control, unstable binocularities, and restricted divergence at both far and near distances.[8–10] Divergence deficits can occur irrespective of convergence and accommodation relaxation, and their appearance at a distance suggests that they do. The physiological studies showing different convergence and divergence modulations at the cortical and subcortical premotor levels support this unexpected finding. Many studiesreveal vergence deficiencies, typically prevalent in people with dyslexia. So, the treatment should specifically target the convergence and divergence subsystems.[10] Motor deficiencies are directly related to dyslexia-related functions.[11]

For those who have dyslexia, these deficiencies will make life more difficult, but they are also easily remedied. Eye care professionals should take several measurements when examining people with dyslexia since it is crucial to spot refractive, accommodative, or binocular irregularities in populations with dyslexia.[12] The findings confirm that dyslexia's phonological deficit are not its underlying cause rather is the cause of the recent discoveries of binocular impairments in dyslexic children.[2]

Therefore, the eye care practitioner must perform a binocular vision evaluation on all children, especially those with reading difficulties. In order to ensure proper diagnosis and treatment for school-aged children who have been identified as having a reading problem, a comprehensive eye examination should include tests for binocular vision and accommodative status, such as near point of convergence (NPC), accommodative facility, amplitude of accommodation, and fusional ranges.[13]

1.2. Objectives

Clinicians and educators need to understand how to diagnose and treat dyslexia and associated vision problems. This review article can provide valuable insights into practical assessment and intervention strategies by summarizing the latest research on these topics. Additionally, this review article can help to identify areas where more research is needed. While there has been some research on the connection between dyslexia and binocular vision, much is still not fully understood. A review article can guide future research efforts by highlighting these gaps in knowledge. Overall, a review article on dyslexia and binocular vision can be a valuable resource for researchers, clinicians, educators, and anyone interested in understanding these conditions and how they may be related.

1.3. Rational

This review paid much attention to the literature about binocular vision parameters in kids with dyslexia worldwide. A study has yet to present an all-encompassing perspective together. Nevertheless, with the assistance of a thorough literature study, we will provide an all-encompassing perspective on the binocular vision parameters in children with dyslexia and its significance in clinical practice in this review.

2. Materials and Methods

In this part, we will cover the approach used to conduct a literature review to investigate the accommodative and vergence parameters among children with dyslexia.

2.1. Eligibility criteria

The literature associated with any binocular vision parameters in children with dyslexia around the globe was given a significant amount of focus in this study. The approach involved examining papers from conferences as well as journal articles, and it also involved initial studies that showed alterations in binocular vision parameters. Our search focused on articles that address visual acuity, stereoacuity, accommodative and vergence parameters in dyslexic children, as these are crucial components of

adequate vision during reading. Studies on dyslexia-related psychological and behavioral alterations, however, were not included. Articles in all languages were considered and translated into English using autoML translation. Much research done and published during 1991 to 2022 on visual deficits and dyslexia were used to inform this study and the age group of the children were considered between 6 -15 years.

2.2. Search strategy

Original and review papers were searched on research repositories including PubMed, Ovid, and Google Scholar. Visual deficits, accommodative inertia, the amplitude of accommodation, near point of accommodation, near point of convergence, fusional vergence, and stereopsis in children with dyslexia were keywords that were included throughout the search. Based on the title and abstract, an initial evaluation was conducted. Selected pieces were thoroughly examined before being included.

2.3. Data extraction

The inclusion applied was binocular vision parameters among children with dyslexia, and the studies related to syndrome and learning disabilities other than dyslexia, disease, and dyslexia, as well as studies with no baseline screening, were excluded. Relevant titles and abstracts were examined. The selected studies were evaluated using a data extraction form that included variables like first author, country, age, gender, and characteristics of dyslexia patients. Outcomes were categorized based on visual criteria evaluations.

2.4. Data synthesis

To provide a qualitative analysis of the included study's findings and components, the information acquired from the relevant research is summarized in the form of tables manually. Investigations of Accommodation & Vergence function in the dyslexic and typical children were compared. Literature management program, Mendeley was used for the evaluation of each study's excellence.

2.5. Study risk of bias assessment

The quality of the included papers was assessed using the ROBINS-I approach for non-randomized trials.[14] Within this approach, the evaluation covered seven distinct themes: confounding, participant selection for the study, classification of interventions, deviations from intended interventions, missing data, assessment of outcomes, and selection of reported results. These themes were thoroughly examined to ensure a comprehensive analysis of potential biases, all while maintaining originality in the write-up.

3. Results

Study selection and characteristics.

3.1. Selection process

One thousand two hundred-five articles were identified in the initial search strategy for all keywords. Twenty-three duplicates and 562 articles were removed for other reasons, and 620 articles were screened. The abstract of 620 articles was inspected, out of which 548 were excluded, and the intention for exclusion is mentioned in the flow diagram strictly following the Preferred Reporting Items for Systematic reviews and Meta-Analyses (PRISMA) guidelines (Diagram 1).[15] All 18 articles were focused on and included. All the Study Design, Characteristics and Risk of bias assessment are summarized in (Table 1).

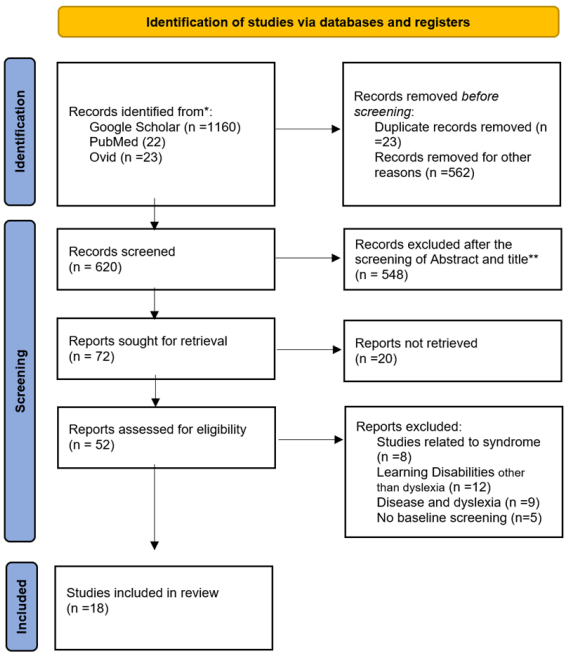

Diagram 1: The flow diagram illustrates the selection process of studies investigating binocular Vision's baseline parameters among children with dyslexia

3.2. Result outcomes

3.2.1. Effect on visual acuity

Visual acuity, when compared between dyslexic and normal child population studies showed no significant differences in distance visual acuity.[2,3,12,13,16] Whereas studies showed a notable distinction in the near visual acuities of the compared groupswhich has been summarized in (Table 2).[3,12,17]

Table 1: Study design, characteristics and risk of bias assessment

Author	Year	Age	Sample size	Study design	Limitation	Country	ROBINS-I
Borsting et al.[6]	2003	8–15	392 Typical Readers	Cross-sectional study	It is important to evaluate the matched group taking into account other factors such as screen time.	California	High
Catalina Palomo-Álvarez et al.[8]	2010	8-13	87 Poor readers 32 Controls	Cross-sectional study	The study should assess the impact of vision therapy on reading tasks for children with poor reading skills.	Spain	Moderate
Buzzelli, Andrew R.[11]	1991	13	13 Dyslexics 13 Normal readers	Cross-sectional study	.....		High
Zoï Kapoula et al.[10]	2007	10.7±2	57 Dyslexics 46 non-dyslexics	Cross-sectional study	Research in this field should combine orthoptic tests, visual training, and recordings of eye movements during reading before and after orthoptic training.	Paris, France	Moderate
Gro Horgen Vikesdal et al.[12]	2019	9-12	17 Dyslexics 17 Controls	Experimental study	It is possible that the high prevalence of hypermetropia in the dyslexic group is due to a small sample size, which could have been affected by the inclusion of more males than females.	Norway	Moderate
Wahlberg-Ramsay et al.[2]	2012	13.8 ± 1.33 14.2 ± 1.67	63 Dyslexics 60 controls	cross-sectional study	.....	Sweden	Moderate
Lisa W. Christian et al.[13]	2017	8.6 ± 2.3	121 Poor readers	Descriptive study	All children from different schools should be included in the study. Randomized controlled trials should be conducted to determine if treating binocular vision conditions can significantly improve children's reading ability. The study should also incorporate additional tests for saccadic eye movements, such as an eye tracker.	Canada	Moderate
Jan Ygge et al[18]	1993	7- 9	86 Dyslexics 86 controls	Longitudinal study	.....	Sweden	Moderate
Wajuihian SO et al.[3]	2011	13 ± 1.42 11.9 ± 0.93	31 Dyslexic Children 31 Controls	cross-sectional study	.....		High
Bruce J. W. Evans et al.[17]	1994	8-15	39 Dyslexic Children 43 controls	cross-sectional study	.....	London	High

Continued on next page

Table 1 continued

Azam Darvishi et al.[16]	2022	8.1 ± 0.8	32 children with dyslexia	Randomized, observational study	Result: Discovered a strong association between the degree of dyslexia and higher near exophoria.	Mashhad, Iran	Moderate
Aparna Raghuram et al.[19]	2018	7-11	29 Developmental Dyslexia 33 Typical Developing	A prospective, uncontrolled observational study	Small sample size and unmasked examiners not amenable to examiner bias or influence.	Boston	Moderate
Hayes et al.[20]	1998	Kindergarten Third grade Sixth grade	297	Randomized, Prospective study	Further study with same standardized NPC method should be implemented with Symptomology questionnaire	California	Moderate
Borsting et al.[21]	1999	8–13	14 (CI) 14 (Normal)	Case control study	Standardized symptom Survey or Questionnaires can be used to know the efficacy of different modes of treatments	California	Moderate
Ramsay et al.[22]	2012	13.80 ± 1.33 14.25 ± 1.67	63 children with dyslexia 60 Controls	cross-sectional study	……..	Sweden	High
Wolfgang Dusek et al.[5]	2010	6-12	810 poor readers 308 controls	Retrospective clinical study	More research is necessary on binocular vision problems in school children with poor reading skills beyond Europe.	Austria	Moderate
M-L Latvala et al.[23]	1994	9-10	82 Dyslexics 84 controls	cross-sectional study	Large sample size and an extended treatment time. Furthermore, a reading comprehension test that measures actual comprehension improvement would be interesting to include.	Finland, Europe	Moderate
Catalina Palomo-Álvarez et al.[24]	2008	8-13	87 poor readers 32 controls	cross-sectional study	It is necessary to study how accommodative treatments affect the reading performance of young readers with low skills.	Spain	Moderate

Table 2: Visual acuity among dyslexic and control group

Author	Sample size	Age (Mean± SD)	Method	Visual AcuityOD/OS/OU (Mean±SD)	P- value
Gro Horgen Vikesdal et al. 2019 [12]	27 children with dyslexia	10.4 ± 1.3	Distance Visual acuity (LogMAR) Near Visual acuity (LogMAR)	OU: 0.09 ± (0.07) OU: 0.03 ± (0.05)	>0.05(Distance)
	27 Controls	10.0 ± 1.1	Distance Visual acuity (LogMAR) Near Visual acuity (LogMAR)	OU: 0.06 ± (0.08) OU: 0.01 ± (0.04)	0.029(Near)
Wajuihian SO et al. 2011 [3]	31 children with dyslexia	13 ± 1.42	Distance Visual acuity (LogMAR)	OD:0.17 ± 0.31 OS:0.20 ± 0.33	OD:0.29 (Distance)
	31 controls	11.90 ± 0.93	Distance Visual acuity (LogMAR)	OD: 0.00 ± 0.24 OS: 0.00 ± 0.24	OS: 0.23 (Near)
Bruce J. W. Evans et al. 1994 [17]	39 children with dyslexia 43 controls	9.5±2.5 9.1±1.8	Near Visual acuity (LogMAR)	Worse in the dyslexic group (Mann-Whitney U-test,)	0.0018
Wahlberg-Ramsay et al. 2012 [12]	63 children with dyslexia	13.80 ± 1.33	Distance Visual acuity (EDTRS chart at 4 m) Near Visual acuity (EDTRS-like chart at 33 cm)	OD: 1.25 ± 0.30 OU: 1.30 ± 0.3 OD: 0.86 ± 0.10 OU: 0.95 ± 0.08	>0.05 (distance and near)
	60 controls	14.25 ± 1.67	Distance Visual acuity (EDTRS chart at 4 m) Near Visual acuity (EDTRS-like chart at 33 cm)	OD: 1.20 ± 0.21 OU: 1.31 ± 0.43 OD: 0.92 ± 0.12 OU: 1.03 ± 0.10	
Lisa W. Christian et al. 2017 [13]	121 Poor readers	8.6 ± 2.3	Distance Visual acuity (LogMAR) Near Visual acuity (LogMAR)	OD:0.04 ± 0.11 OS:0.03 ± 0.11 OU: 0.00 ± 0.08 OD:0.03 ± 0.21 OS:0.03 ± 0.20 OU:0.03 ± 0.20	……
Azam Darvishi et al. 2022 [16]	32 children with dyslexia	8.1 ± 0.8	Distance Visual acuity (LogMAR)	OD:0.002±0.011 OS:0.004±0.018 OU:0.002±0.011	……..

Table 3: Stereo acuity among dyslexic and control group

Author	Sample Size	Age(Mean±SD)	Stereoacuity (Mean±SD)	P-Value
Buzzelli, Andrew R. (1991)[11]	13 Normal readers 13 Children with dyslexia	13±1.9 13±1.5	24±8.77 23.46±15.46	0.677
Bruce J. W. Evans et al. (1994)[17]	43 Normal readers 38 Children with dyslexia	9.5±2.5 9.1±1.8	20 (median) 25 (median)	>0.05
Azam Darvishi et al. 2022[16]	32 children with dyslexia	8.1 ± 0.8	Mild dyslexia: 138.33±100.56 Moderate dyslexia:57±9.48 Severe Dyslexia:106.15±78.05	0.998
Catalina Palomo-Álvarez et al. 2010[8]	87 Poor readers 32 Normal readers	10.5±1.7 10.2±1.5	25.2±11.3 32 23.8±8.6	>0.05
Monireh Feizabadi et al. 2018[25]	27 Children with dyslexia 40 Normal readers	10±2.5 10±2.5	14.8% of dyslexic group worse than 60 s of arc 12.5% of control group worse than 60 s of arc	0.785
Gro Horgen Vikesdal et al. 2019[12]	17 Dyslexics 17 Controls	Children with dyslexia (Children were between 4th and 6th grade) Control (Children were between 4th and 6th grade)	60.00 ± (17.82) 45.00 ± (16.27)	0.018
Zoï Kapoula et al. 2007[10]	57 dyslexics 46 non-dyslexics	10.7±2 10.7±2	<60″ (21%) 60″ (78%) >60″ (1%) <60″ (31%) 60″ (69%) >60″ (0%)	>0.05
M-L Latvala et al.1994[23]	82 dyslexics 84 controls	9±0.4 9±0.5	>60 seconds of arc (9.1%) >60 seconds of arc (8.0%)	>0.05

Table 4: NPC among dyslexic and control group

Author	Sample Size	Age (Mean±SD)	Method	Breakpoint/Recovery point (Mean±SD)	P-Value
Catalina Palomo-Álvarez et al.2010[8]	87 Poor readers	10.5±1.7	Penlight push-up technique (three measurements by the same examiner)	3.7±3.2 / 9.1±5.2	>0.05
	32 Controls	10.2±1.5		4.3±2.3 / 7.9±3.2	
Ramsay et al. 2012[22]	63 children with dyslexia	13.80 ± 1.33	The Royal Air Force (RAF) rule	5.80 ± 1.85 (breakpoint)	<0.001
	60 Controls	14.25 ± 1.67		6.10 ± 2.10 (breakpoint)	
Jameel Rizwana Hussaindeen et al.2018[26]	20 No NSBVA Poor readers	15 ±2.1	Push-up with the accommodative task (three measurements)	7±2.5/ 8 ±0.9	0.005
	46 NSBVA Poor readers	15 ±2.1		9±2.3 / 10±2.25	
Gro Horgen Vikesdal et al. 2019[12]	17 children with dyslexia	Children were between 4th and 6th grade	Push-up with the accommodative task (three measurements)	6.47 ± (2.06) (break)	>0.05
	17 Controls	Children were between 4th and 6th grade		5.56 ± (1.28) (break)	
Wajuihian SO et al. 2011[3]	31 Dyslexic Children	13 ± 1.42	Push-up with accommodative task (three measurements)	8.90 ± 5.03 cm/ 14 ± 5.88 cm	0.049 (break)
	31 Controls	11.90 ± 0.93		12.60 ± 8.70 cm/ 22 ± 8.20 cm	0.06 (recovery)
Monireh Feizabadi et al. 2018[25]	27 Children with dyslexia	10±2.5	push-up technique using an accommodative target (single 20/30 letter).	5.25 ± 1.36	0.33
	40 Controls	10±2.5		4.95 ± 1.17	
Wolfgang Dusek et al. 2010[5]	801 Poor readers	9±3	Penlight push-up technique (three measurements by the same examiner)	4.74 ± 5.59 (break)	< 0.001
	324 controls	9±2.5		3.41 ± 4.62 cm (break)	
Zoï Kapoula et al. 2007[10]	57 dyslexics	10±2.5	Penlight push-up technique	<6cm (break): 44% =6 cm (break):14% 7-10cm(break):36% >10 cm(break): 6%	<0.01
	46 non-dyslexics	10.7±2		<6cm (break): 72% =6 cm (break):13% 7 10cm(break):15% >10 cm(break): 00.0	
Aparna Raghuram et al. 2018[19]	29 Developmental Dyslexics	10.3± 1.2	Push-up with accommodative target	8.00±2.6 /10.57±2.96	0 .01
	33 Typically developing readers	9.4± 1.4		6.30±1.57/ 8.33±1.71	

Table 5: Fusional vergence system among dyslexic and control group

Author	Sample Size	AgeMean±SD	Fusional Vergence Amplitude (Mean±SD)		P-Value
			Distance	Near	
Catalina Palomo-Álvarez et al.2010[8]	87 poor readers	10.5±1.7	BI Break: 9.1±3.0 BI Recovery: 3.6±1.9 BO Blur: 14.2±6.7 BO Break: 19.0±8.3 BO Recovery: 6.0±4.1	BI Blur: 13.0±3.8 BI Break: 18.8±4.7 BI Recovery: 8.9±3.3 BO Blur: 18.8±4.6 BO Break: 26.3±7.7 BO Recovery: 12.2±7.1	(BI- break) = 0.001 (BI recovery) >0.05
	32 control children	10.2±1.5	BI Break: 11.1±3.4 BI Recovery: 5.0±2.4 BO Blur: 11.4±6.0 BO Break: 17.8±6.1 BO Recovery: 7.9±3.5	BI Blur: 11.5±6.6 BI Break: 17.6±5.7 BI Recovery: 9.0±4.45 BO Blur: 18.7±7.8 BO Break: 25.1±7.2 BO Recovery: 12.4±4.8	
Jan Ygge et al 1993[18]	86 dyslexics	2^{nd} & 3^{rd}grade children	BI Break: 6.5±3 BO Break: 16.8±5.3	BI Break: 10.5±2.9 BO Break: 26.5±6.8	>0.05
	86 controls	2^{nd} & 3^{rd} grade children	BI Break: 6.2±2.6 BO Break: 16.8±6.5	BI Break: 10.2±3.2 BO Break: 26.3±7.2	
Wahlberg-Ramsay et al. 2012[2]	63 children with dyslexia	13.80 ± 1.33	BI Break: 10.42 ± 4.46 BO Break: 18.05 ±8.11	BI Break: 11.41 ± 3.49 BO Break: 24.56± 8.43	>0.05
	60 controls	14.25 ± 1.67	BI Break: 9.87± 3.85 BO Break: 19.00± 6.41	BI Break: 12.16 ± 4.57 BO Break: 23.84± 9.16	
Lisa W. Christian et al. 2017[13]	121 Poor readers	10±4	BI Break: 9.41 ± 5.17 BI Recovery:7.44 ± 6.68 BO Break:20.86 ± 10.31 BO Recovery:13.05 ±6.5	BI Break: 13.44 ± 6.40 BI Recovery: 9.77 ± 5.36 BO Break: 21.54 ± 12.37 BO Recovery:15.1 ±8.44	_____
Aparna Raghuram et al. 2018[19]	29 Developmental Dyslexics	10.3± 1.2	BI Break: 6.71±0.36 BI Recovery: 4.20±0.34 BO Break: 18.36±1.61 BO Recovery: 12.12±0.93	BI Break: 11.31±3.13 BI Recovery: 8.28 ±3.19 BO Break: 28.72 ±7.71 BO Recovery: 22.10± 6.25	>0.05 (Distance) 0.01 (Near)
	33 Typically developing readers	9.4± 1.4	BI Break: 7.31±0.32 BI Recovery: 4.86±0.30 BO Break: 16.96±1.44 BO Recovery: 11.12±0.83	BI Break: 11.70 ±2.92 BI Recovery: 8.55±2.88 BO Break: 32.97±7.40 BO Recovery: 26.39±7.13	

Continued on next page

Table 5 continued

Bruce J. W. Evans et al. 1994[17]	24 Dyslexic	9.5±2.5	BI Blur: 9.5±4.5 BI Break: 14.2 ±5.4 BI Recovery: 9.1 ±5.3 BO Blur: 10.9±5.4 BO Break: 15.4±6.7 BO Recovery: 9.5 ±6.5	.....	0.0084 (Break)
	Control 19	9.1±1.8	BI Blur: 14.2 ±7.4 BI Break: 16.1 ±6.2 BI Recovery: 11.6 ±7.0 BO Blur: 16.7 ±9.6 BO Break: 19.0±7.8 BO Recovery: 12.3 ±8.1	.....	0.026 (Recovery)
Wajuihian SO et al. 2011[3]	31 dyslexics	13 ± 1.42	BI Break:14.69 ±6.83 BI Recovery:11.72 ±6.20 BO Break: 27.06±9.25 BO Recovery: 18.76±7.96	BI Break: 11.85±5.14 BI Recovery: 8.77±4.78 BO Break: 21.60±11.62 BO Recovery: 13.35±7.45	0.49 (Distance)
	31 controls	11.90 ± 0.93	BI Break: 16±3.5 BI Recovery: 12.80±3.17 BO Break: 24.16±9.75 BO Recovery: 17±6.93	BI Break:12.83 ±3.13 BI Recovery: 1032±3.35 BO Break:21.09 ±8.42 BO Recovery: 15.55±6.25	0.17 (Near)
Gro Horgen Vikesdal et al. 2019[12]	17 children with dyslexia	10.4 ± 1.3	.....	BI Break: 8.24 ± (3.21)	0.006
	17 Controls	10.0 ± 1.1	.....	BI Break: 11.53 ± (3.18)	

Note: BI: Base In, BO: Base Out

3.2.2. Effects on stereo acuity

In most studies[8,10,11,16,17,23,25] Significance was not found, but a study[12] showed significant differences in the stereo acuities of dyslexic and normal children with the age group between 4th and 6th grade, but the values were still found to be in the normal range hence Dyslexia shows no significant effect on stereopsis; evidence of all the studies is compiled in (Table 3).

3.2.3. Effects on NPC

(Table 4)showing a notable difference in many studies on NPC in dyslexic population.[3,5,10,19–22,26] A possible explanation for these difficulties could be that dyslexia is associated with underlying neurological and cognitive differences. These differences may include problems with visual processing and attention. However, some studies have shown no significant results.[8,12,25]

3.2.4. Effect on fusional vergence system

(Table 5) compiling the studies on fusional vergence, which can affect their ability to read and focus on near objects noted that various research.[8,12,17,19] has suggested that some children with dyslexia may have difficulties with fusional vergence, whereas some studies denied the same.[2,18]

3.2.5. Effect on accommodative facility

(Table 6) presents a summary of the accommodative facility parameters noted in several studies. The studies by[3,5,19,24] found significant statistical differences in the accommodative facility. However, the study by[12] did not observe any statistical differences.

3.2.6. Effect on amplitude of accommodation

In some studies.[5,19,25,27] amplitude of accommodation was observed to be significantly decreased in dyslexic group in comparison with normal child population group and contrasting results were seen in other studies where no difference was seen.[3,16,17,22,24] altogether studies are compiled in (Table 7).

4. Discussion

4.1. Visual acuity

Studies have suggested that children with dyslexia may have difficulties with visual perception, specifically in terms of visual acuity or clarity of vision, such as problems with visual discrimination, spatial orientation, and visual sequencing. At both a distance of 6 meters and a near distance of 40 centimeters, the visual acuity (VA) of distance was affected in a few studies. However, most studies reported hampered near VA in the dyslexic group. This differesnce in visual acuity is because children with dyslexia tend to have a more difficult time processing visual information.[1,12,18,28]

4.2. Stereoacuity

The provided information offers a nuanced perspective on the association between dyslexic individuals and normal subjects, emphasizing the role of factors like stereo acuity in various studies. Most studies did not find statistically significant differences in visual characteristics between dyslexic and non-dyslexic participants, suggesting a lack of consistent distinctions.[16,29].However, a 2019 study[12] stands out by reporting a significant difference in stereo acuity for dyslexic individuals, highlighting potential variations in specific visual processing aspects. Acknowledging the importance of considering study limitations, such as sample size and methodology, is crucial. The findings underscore the need for further research to explore the implications of observed differences in stereo acuity on reading abilities and ascertain whether they are primary or secondary factors associated with dyslexia. Collaborative efforts among researchers are vital to reconcile conflicting results and enhance our understanding of the intricate relationship between dyslexia and visual processing, ultimately contributing to the development of effective interventions for individuals with dyslexia.

4.3. NPC

The mean distance from the point of convergence was found to be reduced in most of the studies for the “dyslexic” group in comparison with the control groups.[3,5,10,19–22,26] Similar seen in the convergence insufficient population (p= 0.027).[21] The study also found that the NPC break and recovery varied considerably across children in kindergarten, third grade, and sixth grade, suggesting that the age of the dyslexic population should also be taken into account when diagnosis. One of the reasons is associated with underlying neurological and cognitive differences, including problems with visual processing and attention.[20,28,30,31]

4.4. Fusional vergence testing

Present review of literature has suggested that some children with dyslexia may have fusional vergence difficulties, affecting their ability to read and focus on near objects. Studies found that children with dyslexia had reduced fusional vergence amplitudes compared to typically developing children, indicating a reduced ability to maintain binocular vision while looking at near objects.[8,12,17,19] This difficulty in fusional vergence may contribute to visual discomfort and fatigue while reading, exacerbating reading difficulties in children with dyslexia.[28] However, it is essential to note that not all children with dyslexia experience problems with fusional vergence and that many other factors can contribute to reading difficulties in these children. Treatment for dyslexia typically focuses on improving language-based skills, such as phonological

Table 6: Accommodative facility among dyslexic and control group

Author	Sample Size	Age (Mean±SD)	BAF/MAF (Cycle Per Minute) (Mean±SD)	P-Value
Lisa W. Christian et al. 2017 [13]	121 Poor readers	8.6 ± 2.3	OD: 9.15 ± 3.24 OS: 9.53 ± 3.54 OU: 9.35 ± 3.84	>0.05
Aparna Raghuram et al. 2018 [19]	29 Developmental Dyslexics	10.3± 1.2	5.26±2.79/4.89±2.94	< .001 (MAF)
	33 Typically developing readers	9.4± 1.4	6.97±3.24/7.27±2.52	>0.05 (BAF)
Wajuihian SO et al. 2011 [3]	31 Dyslexic Children	13 ± 1.42	6.86 ± 2.74	= 0.03
	31 Controls	11.90 ± 0.93	8.85 ± 3.69	
Wolfgang Dusek et al. 2010 [5]	810 poor readers	9±3	6.51 ± 3.83	< 0.01
	308 controls	9±2.5	9.00 ± 3.46	
Gro Horgen Vikesdal et al. 2019 [12]	17 Dyslexics	Children with dyslexia (Children were between 4th and 6th grade)	6.41 ± (3.61)	>0.05
	17 Controls	Control (Children were between 4th and 6th grade)	7.06 ± (3.21)	
Catalina Palomo-Álvarez et al. 2008 [24]	87 poor readers	10.5±1.7	4.9±3.1	<0.001 (MAF)
	32 controls	10.2±1.5	6.3±2.9	< 0.05 (BAF)

Note BAF: Binocular Accommodative Facility, MAF: Monocular Accommodative Facility

awareness and decoding, rather than solely targeting fusional vergence. [31]

4.5. Accommodation accuracy

Accommodative latency of what was found to be optimal represents results within the range of what is considered normal, according to Scheiman and Wick. [32] Children diagnosed with developmental coordination deficit (DCD) had significantly worse accommodative accuracy (without the use of lenses) than children who served as controls· [1] According to the outcomes of the binocular facility test, it was discovered that DCD had an accommodation facility of lower quality than controls. Compared to typically developing readers, individuals with developmental dyslexia exhibit significantly lower levels of both monocular and binocular accommodative facility. [1,19]

The amplitude of accommodation was assessed using the push-down method. The Amplitude of Accommodation values were inverted to make sense in the upright position. Results for the push-up were dramatically better than those for the push-down. [30] According to statistical analysis, monocular (P = 0.025) and binocularly (P = 0.013), the dyslexic group showed noticeably decreased accommodation amplitude. [28,29] The amplitude of accommodation was reduced in the dyslexic group [17] (p <0.006) binocularly as well as monocularly (p <0.0014) compared to the control group. [19] The groups exhibited significant differences in both the amplitude of accommodation (F = 13.67) and monocular accommodative facility (F = 18.11) (P < .001 for both). The dyslexic group exhibited a statistically significant decrease in near point of accommodation (NPA) when assessed monocularly and binocularly. [5,25]

4.6. Implications

It is necessary to evaluate the distance and near visual acuity, but a significant effect is seen in the near visual acuity; careful examination for near acuity in dyslexic children is necessary, as it can help to know their difficulty level while performing near tasks. The near point of convergence was noted to be receded in dyslexic children. These differences could affect the ability of the eyes to coordinate when focusing on near objects, leading to problems with near tasks specifically. Consider age concerning the normative value.

Optometric therapies that address fusional vergence may be beneficial for some dyslexic children who feel visual discomfort while reading, as it has been observed that alteration in fusional vergence system in dyslexic children.The affected ability of the eyes to focus on stimuli at varying distances is reported in dyslexic children, which causes ocular discomfort, eyestrain, fatigue, vision impairment, headache, and difficulties in focusing and concerning therapies that can reduce such symptoms. One clinical implication of these findings is that an optometric specialist should examine monocular accommodative amplitude and binocular accommodative capability in children with low reading levels.

Table 7: Amplitude of accommodation among dyslexic and control group

Author	Sample Size	Age (Mean±SD)	Amplitude of Accommodation (Mean±SD)	P-Value
Ramsay et al. (2014)[22]	63 children with dyslexia	13.80 ± 1.33	Monocular (OD): 12.09D ± 2.65 Binocular: 13.10D ± 2.34	>0.05
	60 Controls	14.25 ± 1.67	Monocular (OD): 13.30D ± 3.24 Binocular: 14.42D ± 2.10	
Bruce J. W. Evans et al. (1994)[17]	39 children with dyslexia	9.5±2.5	OD: (Median)14.0	> 0.10
			OS: (Median) 13.9	
			OU: (Median)16.0	
	43 controls	9.1±1.8	OD: (Median)16.8	
			OS: (Median) 18.0	
			OU: (Median)20.0	
Aparna Raghuram et al. 2018[19]	29 Developmental Dyslexia	10.3± 1.2	Binocular: 10.18D ± 1.99	< .001
	33 Typical Developing	9.4± 1.4	Binocular: 11.77D ± 1.42	
Monireh Feizabadi et al.2018[25]	27 Children with dyslexia	10±2.5	OD: 6.90 ± 1.23 cm (NPA)	
			OS:7.32 ± 1.68 cm (NPA)	0. 049
			OU: 6.66 ± 1.21 cm (NPA)	
	40 Controls	10±2.5	OD: 5.98 ± 1.15 cm (NPA)	
			OS:6.23 ± 1.20 cm (NPA)	
			OU: 6.00 ± 1.38 cm (NPA)	
Catalina Palomo-Álvarez et al. 2008[24]	87 poor readers	10.5±1.7	Monocular AOA OD: 9.1±2.3 Monocular AOA OS: 9.0±2.3	>0.05
	32 controls	10.2±1.5	Monocular AOA OD: 10.5±1.7 Monocular AOA OS: 10.5±1.8	
Kristen Kerber et al. 2017[[27]	30 dyslexic individuals	10.29±1.17	Binocular: 10.21± 2.04	0.05
	33 typically reading children	9.44±1.38	Binocular: 11.5±1.48	
Wajuihian SO et al. 2011[3]	31 Dyslexic Children	13 ± 1.42	OD: 11.98 ± 2.34 D OS: 12.14 ± 2.15 D	>0.05
	31 Controls	11.90 ± 0.93	OD: 12.87 ± 1.08 D OS: 12.87 ± 1.16 D	
Wolfgang Dusek et al. 2010[5]	810 poor readers	9±3	OU: 12.54D ± 2.60D	< 0.001
	308 controls	9±2.5	OU: 13.29D ± 2.05D	
Azam Darvishi et al. 2022[[16]	32 children with dyslexia	8.1 ± 0.8	Mild dyslexia: OU: 8.2±2.3 Moderate dyslexia: OU: .9.8±2.6 Severe dyslexia: OU: 8±1.3	0.934

5. Limitations of the Evidences

In addition to the findings of a comprehensive ophthalmologic examination and a full literacy assessment, examinations of vergence, accommodation, and eye movement may be helpful in the first evaluation of children with dyslexia. When assessing people with dyslexia, consider cycloplegia. More study is needed to determine the role of binocular vision on reading comprehension, performance, and fluency. Studying the effects of orthoptic training on reading performance requires combining orthoptic exams with visual instruction and documenting eye movements before and after the intervention.

6. Conclusion

The present review of literature findings did not provide evidence to support the notion that dyslexic children are more susceptible to any visual condition. However, it is worth noting that some vision abnormalities were more common among persons with dyslexia compared to the control group. While specific vision deficits appeared more common in the dyslexic community than the control population, the findings on dyslexia and vision conflict. However, for children to display their full potential, any visual impairment should be identified as early as possible and suitable accommodations should be made for them. They present a comprehensive assessment of the probable relationships between dyslexia and visual factors, notwithstanding the limitations of the studies that came

before them. A list of conditions that have been investigated concerning their impact on dyslexia may be helpful for eye care specialists, educators, and other professionals who work with children with dyslexia. This list can be found in the present review of literature. Thus, the present review is expected to assist eye care professionals in clinical decision making while managing children with dyslexia.

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References

1. Goldish M. Everything you need to know about dyslexia. New York: The Rosen Publishing Group, Inc; 2000.
2. Wahlberg-Ramsay M, Nordström M, Salkic J, Brautaset R. 2012. Available from: https://doi.org/10.3109/09273972.2012.735335.
3. Wajuihian SO, Naidoo KS. A Comparison of the Visual Status of Dyslexic and Non-Dyslexic Schoolchildren in Durban, South Africa. *Afr Vis Eye Health*. 2011;70(1):29–43.
4. N-Szwedo E, Alramis F, Christian LW. Association between Fine Motor Skills and Binocular Visual Function in Children with Reading Difficulties. *Hum Mov Sci*. 2017;56(1):1–10.
5. Dusek W, Pierscionek BK, Mcclelland JF. A Survey of Visual Function in an Austrian Population of School-Age Children with Reading and Writing Difficulties. *BMC Ophthalmol*. 2010;10(1):16.
6. Borsting E, Rouse MW, Deland PN, Hovett S, Kimura D, Park M, et al. Association of Symptoms and Convergence and Accommodative Insufficiency in School-Age Children. *J Optom*. 2003;74(1):25–34.
7. Abdi S, Brautaset R, Rydberg A, Pansell T. The Influence of Accommodative Insufficiency on Reading. *Clin Exp Optom*. 2007;90(1):36–43.
8. Palomo-Álvarez C, Puell MC. Binocular Function in School Children with Reading Difficulties. Graefe's Arch. *Clin Exp Ophthalmol*. 2009;248(6):885–92.
9. Stein J. *Neuropsychologia*. 2003;41(13):1785–93. Available from: https://doi.org/10.1016/S0028-3932.
10. Kapoula Z, Bucci MP, Jurion F, Ayoun J, Afkhami F, Brémond-Gignac D. Evidence for Frequent Divergence Impairment in French Dyslexic Children: Deficit of Convergence Relaxation or of Divergence per Se? Graefe's Arch. *Clin Exp Ophthalmol*. 2006;245(7):931–937.
11. Buzzelli AR. Accommodative and Vergence Facility: Do They Relate to Dyslexia? *Optom Vis Sci*. 1991;68(11):842–6.
12. Vikesdal GH, Mon-Williams M, Langaas T. Optometric Disorders in Children and Adults with Dyslexia. *Scand J Educ Res*. 2020;64(4):601–11.
13. Christian LW, Nandakumar K, Hrynchak PK, Irving EL. Visual and Binocular Status in Elementary School Children with a Reading Problem. *J Optom*. 2018;11(3):160–166.
14. Sterne JAC, Hernán MA, Reeves BC, Savović J, Berkman ND, Viswanathan M, et al. ROBINS-I: a tool for assessing risk of bias in non-randomised studies of interventions. *BMJ*. 2016;12(October):355–i4919.
15. Yepes-Nuñez JJ, Urrútia G, Romero-García M, Alonso-Fernández S, The P. Statement: An Updated Guideline for Reporting Systematic Reviews. *Rev Esp Cardiol*. 2021;74(9):790–99.
16. Darvishi A, Rad DS, Atigh SBQ, Hamidi A, Shandiz JH, Baghini AS. The Relation between the Severity of Reading Disorder and Visual Functions among Children with Dyslexia. *Taiwan J Ophthalmol*. 2022;12(2):178–83.
17. Evans BJ, Drasdo N, Richards IL. Investigation of Accommodative and Binocular Function in Dyslexia. *Ophthalmic Physiol Opt*. 1994;14(1):5–19.
18. Ygge J, Lennerstrand G, Rydberg A, Wijecoon S, Pettersson BM. Oculomotor Functions in a Swedish Population of Dyslexic and Normally Reading Children. *Acta Ophthalmol*. 1993;71(1):10–21.
19. Raghuram A, Gowrisankaran S, Swanson E, Zurakowski D, Hunter DG, Waber DP. Frequency of Visual Deficits in Children with Developmental Dyslexia. *JAMA Ophthalmol*. 2018;136(10):1089–95.
20. Hayes GJ, Cohen BE, Rouse MW, De Land P. Normative Values for the Nearpoint of Convergence of Elementary Schoolchildren. *Optom Vis Sci*. 1998;75(7):506–12.
21. Borsting E, Rouse MW, Land P. Prospective Comparison of Convergence Insufficiency and Normal Binocular Children on CIRS Symptom Surveys. *Optom Vis Sci*. 1999;76(4):221–8.
22. Ramsay MW, Davidson C, Ljungblad M, Tjärnberg M, Brautaset R, Nilsson M. Can vergence training improve reading in dyslexics? *Strabismus*. 2014;22(4):147–51.
23. Latvala ML, Korhonen TT, Penttinen M, Laippala P. Ophthalmic Findings in Dyslexic Schoolchildren. *Br J Ophthalmol*. 1994;78(5):339–43.
24. Palomo-Álvarez C, Puell MC. Accommodative Function in School Children with Reading Difficulties. Graefe's Arch. *Clin Exp Ophthalmol*. 2008;246(12):1769–74.
25. Feizabadi M, Jafarzadehpur E, Akrami M. Accommodation, Convergence, and Stereopsis in Dyslexic Schoolchildren. *Middle East Afr J Ophthalmol*. 2018;25(1):14–8.
26. Hussaindeen JR, Shah P, Ramani KK, Ramanujan L. Efficacy of Vision Therapy in Children with Learning Disability and Associated Binocular Vision Anomalies. *J Optom*. 2018;11(1):40–8.
27. Kerber K, Gowrisankaran S, Swanson EA, Waber D, Raghuram A. Ocular Accommodation Deficits and near Work Associated Symptoms in Children with Dyslexia. *Invest Ophthalmol Vis Sci*. 2017;58(8):5429.
28. Bosch-Bayard J, Peluso V, Galan L, Sosa PV, Chiarenza GA. Clinical and Electrophysiological Differences between Subjects with Dysphonetic Dyslexia and Non-Specific Reading Delay. *Brain Sci*. 2018;8(9):172.
29. Bilbao C, Piñero DP. Diagnosis of Oculomotor Anomalies in Children with Learning Disorders. *Clin Exp Optom*. 2020;103(5):597–609.
30. Schulte-Körne G. Diagnostik Und Therapie Der Lese-Rechtschreib-Störung Gerd Schulte-Körne. *Dtsch Arztebl Int*. 2010;107(41):718–27.
31. Shaywitz SE, Shaywitz BA, Fletcher JM, Escobar MD. Prevalence of Reading Disability in Boys and Girls: Results of the Connecticut Longitudinal Study. *JAMA J Am Med Assoc*. 1990;264(8):998–1002.
32. Mitchell S, Bruce W. Clinical Management of Binocular Vision: Heterophoric, Accommodative, and Eye Movement Disorders. vol. 4. United States: LWW; 2013. p. 65.

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