Supplementary Online Content

This supplementary material has been provided by the authors to give readers additional information about their work.

eAppendix. Methods

Standard Eye Examination: A complete standard eye examination with a detailed visual function assessment and cycloplegic refraction was performed. This examination included eye and general health history, visual acuity for distance and near, eye movements, pupillary function, cover test for eye alignment, stereopsis (3D), refraction (dry and cycloplegic), slit lamp examination of the lids, lashes, conjunctiva, sclera, cornea, anterior chamber, iris, lens, anterior vitreous and intraocular pressure. Visual function assessment (detailed below) followed and the examination was completed with a dilated fundus examination.

Visual Function Assessment:
    Vergence:
    Near point of convergence (NPC): NPC was assessed using an accommodative target. The test provides estimates of the extent of convergence (amplitude) measured as the distance between the lateral canthus to when the target was reported to be seen as double by the patient (in cms).

    Fusional ranges: Positive (convergence) and negative (divergence) ranges were measured using prism bars, providing estimates of the maximum extent to which the eyes can converge and diverge. Prism bars were introduced while the child looked at a single letter target 20/40 in letter size, for distance and near, and slowly increased initially at 2 prism diopters per second. At 20 prism diopter level the diopter change was changed to 5 prism diopters (the dioptric change in the prism bars). The prism bars were oriented in the appropriate direction and the child was asked to report when it split into two (double), and when it returned back to single. These findings were recorded as break and recovery respectively in prism diopters (Δ). The break value was recorded as the convergence or divergence amplitude.

    Vergence facility: Vergence facility was measured with a 12Δ base-out /3Δ base-in flipper. The test provides information on the eye's ability to move with ease from a convergence (base out prism) demand to a divergence (base in prism) demand (net change of 15Δ) and vice versa. The child was presented a letter target to fixate at 40 cm along the midline in a slight downgaze. The prism flipper was alternated between the 12Δ base out and 3Δ base in and the participant was to report when the fixated target appeared single and in focus. One cycle indicates the ability to clear both the base out and base in side of the prism. The number of cycles cleared in 1 minute was recorded.

    Accommodation:
    Amplitude of Accommodation: Amplitude of accommodation was assessed under monocular and binocular viewing conditions, providing an estimate of the maximum ability (distance) that the eye can focus and keep the print seen clear. Children looked at a 20/30 reduced Snellen chart as it is moved closer to their face and asked to report when they experienced sustained blur and were unable to maintain focus, even with effort. The distance from the chart to the lateral canthus was measured as the near point of accommodation value (in cms and converted to dioptric measure for the amplitude). The measurement was obtained two times per eye and an average was determined for each viewing condition.

    Accommodative Facility: Accommodative facility was assessed using ± 2.00 D flipper under monocular and binocular viewing conditions, indicative of how well the accommodative system can respond dynamically to relax and focus (e.g., looking at the board to reading a book and back and forth). Participants viewed an accommodative rock card, which displays three to five letter words of 20/30 letter size, and were asked to read the word as each side of the flipper is placed in front of their eyes. One cycle is the ability to clear the plus and the minus side of the lens. The number of cycles completed in 1 minute was recorded.

    Accommodative accuracy: This measure assesses how accurate the accommodative system is to a demand, for example when reading a book. Participants were asked to look at a card displaying first grade level words at 40 cms. The card was placed on the retinoscope head, an instrument used to measure the refractive status of the eye. The dioptric lens power needed to neutralize the observed reflex was measured for each eye.

Ocular Motor Tracking (Versions):

Developmental Eye Movement Test (DEM): The DEM is a visual – verbal clinical ocular motor assessment tool. Participants were shown displays of numbers arranged vertically and horizontally and asked to call them out. The test contains three test plates. Test A and Test B contain vertically arranged numbers in two columns. Test C contains horizontally arranged numbers. The time to complete each test plate and the errors were recorded. Test A and B provide an estimate of visual processing speed and the ratio between horizontal to vertical measures tracking. All raw scores were converted to standard scores for analysis.

Eye Movements During Reading (Visagraph). Eye movements (horizontal position of both eyes) while reading standardized text paragraphs (grade 1- 5 equivalent) were recorded with a Visagraph eye tracker (Taylor Associates, Huntington, NY), an infrared, limbal-reflection eye movement recording system. The text was chosen based on the child's reading grade level, as estimated by their performance on the WRMT Word Identification task. Children wore goggles containing infra-red sensors and emitters and read the text binocularly at their habitual reading distance in a primary position. They first read two practice paragraphs at their reading grade level to assure a stable baseline, after which they read a new paragraph and answered 10 yes/no questions related to details of the paragraph. The children were instructed to read the paragraphs using their normal reading strategy, and to pay attention to text details, as they would be tested for comprehension at the end of reading, but they were instructed not to reread.   The software automatically calculated values for each parameter, including the following: reading rate in words per minute (wpm), number of progressive saccades as fixations/100 words, number of regressive saccades as regressions/100 words, and comprehension as a percentage of correct answers.

eTable 1. Vergence and Accommodation Deficit Diagnosis and their Diagnostic Criteria Based on a Battery of Visual Function Assessment

Convergence Insufficiency (at least 2 of the following criteria must be met for diagnosis)	
Test	**Failure Criteria**
Near Point of Convergence (with an accommodative target)	> 7cm
Exophoria at near	≥ 4^Δ than at distance
Positive Fusional Vergence (PFV)	< 20^Δ break, or if Sheards criterion is not met (that the PFV measures less than twice the magnitude of the near phoria)
Vergence Facility	≤ 9 cpm; difficulty clearing the base out prism
Convergence Excess (at least 2 of the following criteria must be met for diagnosis)	
Esophoria at near	≥ 2^Δ
Negative Fusional Vergence (NFV)	≤ 8^Δ break , or if Sheards criterion is not met (that the NFV measures less than twice the magnitude of the near phoria)
Vergence Facility	≤ 9 cpm and/or failing base-in prism.
Accommodative Insufficiency (at least 2 of the following criteria must be met for diagnosis)	
Amplitude of Accommodation	2D less than (15- ¼ ×age)
Monocular Accommodative Facility	≤ 6 cpm and difficulty clearing minus lens
Accommodative Response Accuracy	High lag of accommodation > 1.00 D
Accommodative Dysfunction (both criteria must be met for diagnosis)	
Amplitude of Accommodation	2D less than (15- ¼ ×age)
Monocular Accommodative Facility	≤ 6 cpm and difficulty clearing plus lens
Accommodative Infacility	
Monocular Accommodative Facility	≤ 6 cpm and difficulty clearing plus and minus lens

cpm = cycles per minute; Δ = prism diopter.

eTable 2. Cover Test Findings at Near

	Exophoria	Esophoria	Orthophoria	Mean ± SD
Typical Readers	17	8	8	0.88Δ ± 3.43
Developmental Dyslexic	5	12	12	-0.85Δ ± 3.42

Δ prism diopters, + exo, - eso

eTable 3. Vergence Clinical Test Results in Developmental Dyslexic and Typical Developing Readers

VERGENCE - Clinical tests		Developmental Dyslexic (DD)		Typical Developing (TD)		
		Mean	SD	Mean	SD	ANCOVA
Near Point of Convergence	accommodative target -break	8.00	2.66	6.30	1.57	F(1,61) = 6.48, P = .01
	accommodative target - recovery	10.57	2.96	8.33	1.71	F(1,58) = 10.17, P = .002
Fusional Ranges Distance (Δ)	Divergence break	6.71	0.36	7.31	0.32	NS
	Divergence recovery	4.20	0.34	4.86	0.30	NS
	Convergence break	18.36	1.61	16.96	1.44	NS
	Convergence recovery	12.12	0.93	11.12	0.83	NS
Fusional Ranges Near (Δ)	Divergence break	11.31	3.13	11.70	2.92	NS
	Divergence recovery	8.28	3.19	8.55	2.88	NS
	Convergence break	28.72	7.71	32.97	7.40	F(1,62) = 6.48, P = .01
	Convergence recovery	22.10	6.25	26.39	7.13	F(1,62) = 9.1, P = .004
Near Vergence Facility (cpm)	Prism flipper 3 Δ BI/12ΔBO	11.34	0.93	14.21	0.83	NS

SD = standard deviation; Δ = prism diopters; BI = base in; BO = base out; cpm = cycles per minute; NS = not significant

eTable 4. Accommodation Clinical Test Results in Developmental Dyslexic and Typical Developing Readers

| ACCOMMODATION - Clinical Tests		Developmental Dyslexic (DD)		Typical Developing (TD)		
		Mean	SD	Mean	SD	ANCOVA
Amplitude of Accommodation (D)	Push up method	10.18	1.99	11.77	1.42	F(1,57) = 13.67, P < .001
Monocular Accommodative Facility (cpm)	± 2.00 - Flipper	4.89	2.94	7.27	2.52	F(1,57) = 18.11; P < .001
Binocular Accommodative Facility (cpm)	± 2.00 - Flipper	5.26	2.79	6.97	3.24	NS
Accommodative Accuracy (D)	Near Retinoscopy at 40cms	0.94	0.41	0.75	0.32	NS

D = diopters; cpm = cycles per minute; NS = not significant

eTable 5. Correlations Between Developmental Eye Movement Parameters and Visagraph Eye Tracker Parameters for all Subjects

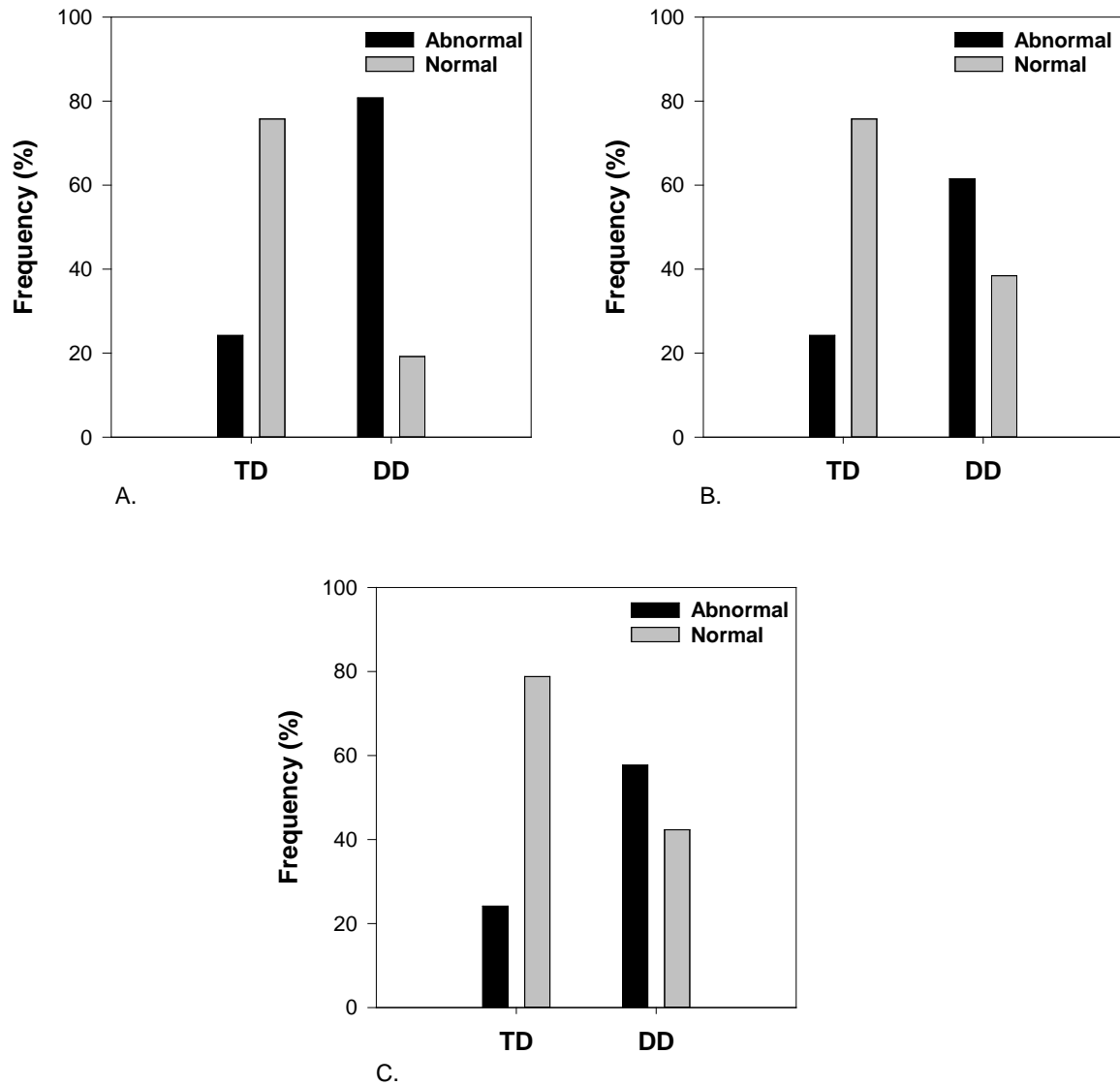|		Visagraph Reading Rate (wpm)	Visagraph Fixations (per 100 words)	Visagraph Regressions (per 100 words)
DEM Vertical Score	Pearson Correlation	.373[**]	-.393[**]	-.371[**]
	Sig. (2-tailed)	.004	.002	.004
	N	59	59	59
DEM Horizontal Score	Pearson Correlation	.494[**]	-.514[**]	-.490[**]
	Sig. (2-tailed)	.000	.000	.000
	N	59	59	59
DEM Errors	Pearson Correlation	.334[**]	-.303	-.376[**]
	Sig. (2-tailed)	.010	.020	.003
	N	59	59	59

[**]. Correlation is significant at the 0.01 level (2-tailed).
DEM - Developmental Eye Movement Test

eFigure 1. Distribution of Abnormal vs Normal DEM Scores

DEM - Errors

DEM - Horizontal score

A.

B.
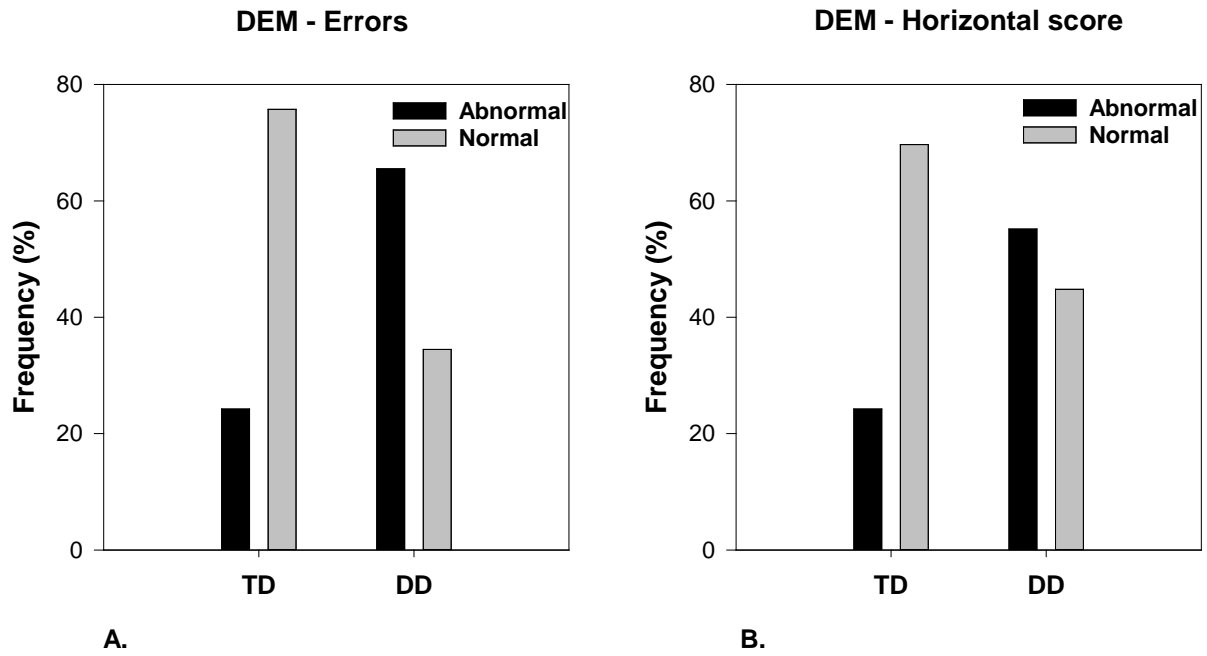
A. Distribution of abnormal vs normal DEM error scores for Typical Developing Readers (TD) and Developmental Dyslexia (DD) groups (χ^2 (1,62) = 10.70, P < .001) **B.** Distribution of abnormal vs normal DEM horizontal scores in TD and DD group (χ^2 (1,62) = 6.22, P = .01).

eFigure 2. Distribution of Abnormal vs Normal Performance on the Visagraph Eye Tracking Parameters

A-C: Distribution of abnormal (black bars) vs normal (gray bars) performance on the Visagraph eye tracking parameters (**A:** Reading rate, **B:** Fixations, **C.** Regressions) for Typical Readers (TD) and Developmental Dyslexia (DD) groups (combined DD subgroups). For all parameters, the DD group had significantly larger number of participants failing the test compared to TD (reading rate, $\chi^2_{(1,59)}$ = 18.59; P<.001, fixations, $\chi^2_{(1,59)}$ =8.38; P=.004, regression, $\chi^2_{(1,59)}$ =8.28; P=.004 respectively).