Article • Early Detection of Visual Dysfunction in 5th and 6th Grade Readers Based on Head Movements and Head Position During Reading Activities

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ABSTRACT

Purpose: An investigation into the relationship between head movements while reading and visual dysfunction in children. This study was designed as an attempt to validate commonly held optometric beliefs that visual symptoms can manifest as head tilts, head movements, or head position close to reading material.

Methods: Head movements were tracked with a webcam while 5th- and 6th-grade students, ages 10 and 11, were reading for fifteen minutes. Head movement behaviors were then compared to their vision screening results and a teacher observation checklist filled out by their classroom teachers.

Results: A total of 24 subjects participated in the study. Head movement differences were subjectively noted between subjects, although objectively, no significant correlations were found between head movements, vision data, or the teacher observation checklist.

Conclusion: The lack of literature in the area of head movements while reading and a child's visual system may be in part due to the difficulty of analyzing such behaviors objectively and habitually at the same time; alternatively, it may be because no such correlation is present.

Keywords: head movements, reading, teacher observation, vision screening

Introduction

Many studies within the fields of optometry and education have found a relationship between reading performance and a child's visual function.[1-10] Some of the visual factors found to affect reading performance are refractive error (nearsightedness, farsightedness), anisometropia (significant difference of power between the two eyes), oculomotor skills (eye movements), accommodation (ability to focus), and binocularity (ability of the two eyes to work together).[1-3,6] Additionally, Kulp and Schmidt demonstrated that "good visual perceptual skills are significantly associated with whether a child will show successful or reduced reading performance."[1] In line with these findings, The American Optometric Association (AOA) and the College of Optometrists in Vision Development (COVD) have created and distributed a list of "Signs of Eye and Vision Problems" to watch out for in children. These include frequent eye rubbing or blinking, short attention span, avoiding reading or other close activities, frequent headaches, covering one eye, tilting the head to one side, holding reading material too close to the face, an eye turning in/out, seeing double, and losing place while reading.[11,12] Although gross head movement and positioning (tilting the head and positioning the head too close to reading material) appear on prominent symptom checklists such as the one published by the AOA, unlike the visual skills listed above, there

is a gap in the literature validating the use of head movements to determine the state of a child's visual system.[11] The limited publications regarding head movements while reading were designed to look at the propensity of head movements during reading tasks and did not look at head movements in relation to visual skills. However, they showed that head movements were suppressed while reading, possibly to stabilize fixation during reading tasks.[13-15] This indicates that excessive head movements are possibly disruptive to reading.

It is estimated that 25% of children ages 5 to 17 have vision-related learning difficulties, with 79% of these not having seen an eye doctor in the past 12 months. Additionally, many of these children have not received a vision screening in the last 12 months.[17-19] It is accepted that children spend the majority of their day in the classroom with their teachers; therefore, teachers are in a perfect position to help make educated referrals for their students who may need vision care.[20] If we are able to help improve the accuracy by which a teacher refers a student, the large number of children with undiagnosed and untreated visual difficulties may decrease. On the checklist published by the AOA, head movements are the most obvious behavior for a teacher to observe across a classroom. This, in conjunction with the lack of literature in the area of head movements during reading and their correlation to the visual system, informed the questions in this study.

This study will use head position measurements, taken continuously while the participant reads, to determine the participant's gross head movement and position behaviors while reading. These results will then be analyzed in relation to measurements from a comprehensive vision screening. The aim is to determine whether these gross head movements are indicative of visual problems and, if so, suggestive of the need for a vision examination by an optometrist. If gross reading behaviors can be linked to dysfunctions in a child's visual system, we can both validate the checklists currently in circulation and create new protocols to help teachers more easily identify students in need of visual interventions.

Methods

All procedures and protocols used in this study were approved by the Pacific University Institutional Review Board. Twenty-four 5th- and 6th-grade students, ages 10 and 11, from a predominantly Hispanic, lower socio-economic elementary school in Forest Grove, Oregon, participated in the study to completion. This included both the reading portion of the study and the vision screening. Pacific University College of Optometry previously had partnered with this elementary school to provide vision screenings to the students who had been referred by their teachers. The referral-based model was implemented at this school due to the large enrollment of 841 students and the lack of resources to provide vision screenings for all of the students. All students referred by their teachers were invited to participate in the study. The small sample in the final study (N=24) was constrained by the number of students who submitted their parental permission forms and the loss of several research days due to multiple school closures for snow. Parents signed two separate consent forms, one for their child to participate in the vision screening and another for their child to participate in the reading portion of the study. Additionally, students provided a verbal assent to participate in the reading portion.

The vision screening included visual acuities, refractive error determination with the SPOT auto-refractor, stereo acuity, cover testing near and far, near point of convergence, ocular motilities, accommodative facility testing with lens flippers, the NSUCO oculomotor test, and the Wold sentence copy test.[21,22]

Figure 1. *Example of FaceAPI while recording. The actual video of the subject is never stored on the computer, and is only used to line up the subject initially.*

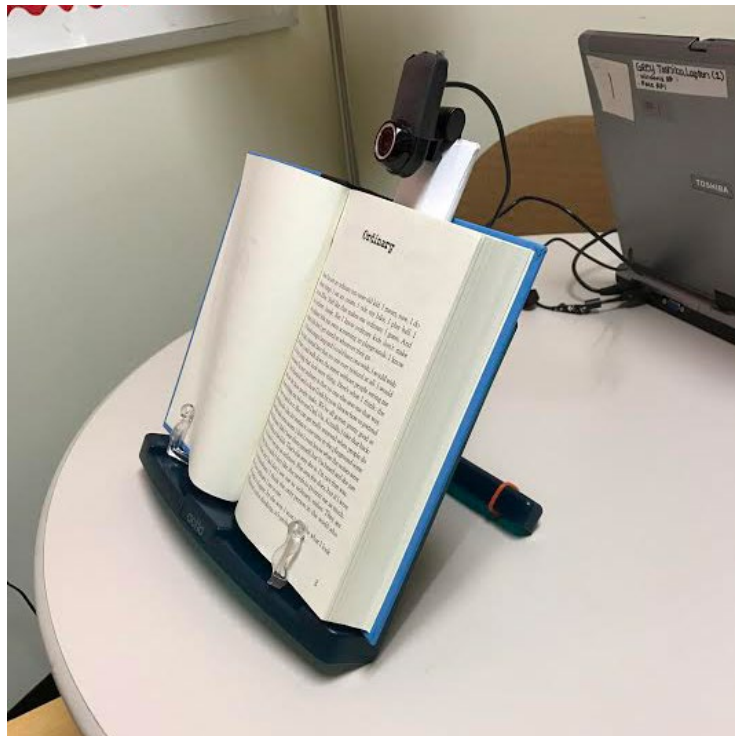

Figure 2. *Head movement recording set-up while reading*

After a student completed the screening, the principal investigators reviewed the student's vision screening results and determined whether the student was eligible for the study. Students who reported or presented with strabismus or amblyopia during the vision screening were excluded from the study. In addition, students who fell at or below a third-grade reading proficiency were also excluded.

Equipment

The first generation of FaceTrackNoIR and FaceAPI* software was used to record the head position measurements in x, y, and z coordinates, as well as rotation around the x, y, and z axes (Figure 1). This program was installed on a password-protected laboratory laptop, which was connected to a standard Sony digital webcam with 1920 x 1080 resolution, 60Hz frame rate, and 2 x 2 x 4 cm (WxHxD) dimension. The FaceAPI program was used to access the video stream of the webcam and obtain the inter-ocular distance on the captured video based on geometric features (eyes, nose, cheeks and mouth). These measurements were taken every 500 ms and placed in bins of 30 samples. The actual head position measurements were then determined by comparing the measured inter-ocular distances to the program-assumed distances. The program used an assumed viewing distance of 78.4 centimeters and an inter-ocular distance of 6.35 centimeters.

Set-up

The webcam was attached to the top of the reading-level-appropriate book, *Wonder* by Raquel J. Palacio, and the book was placed on a reading stand (Figure 2). Although placing the book on a stand detracts from the student reading like they do in the classroom, it was necessary to help differentiate head movements versus book movement if the student had otherwise been holding the book.

Reading took place in an office with the participant's back to the door. The participants were asked to read silently in their

* This generation is no longer supported but can be downloaded here: http://bit.ly/34ebmpd

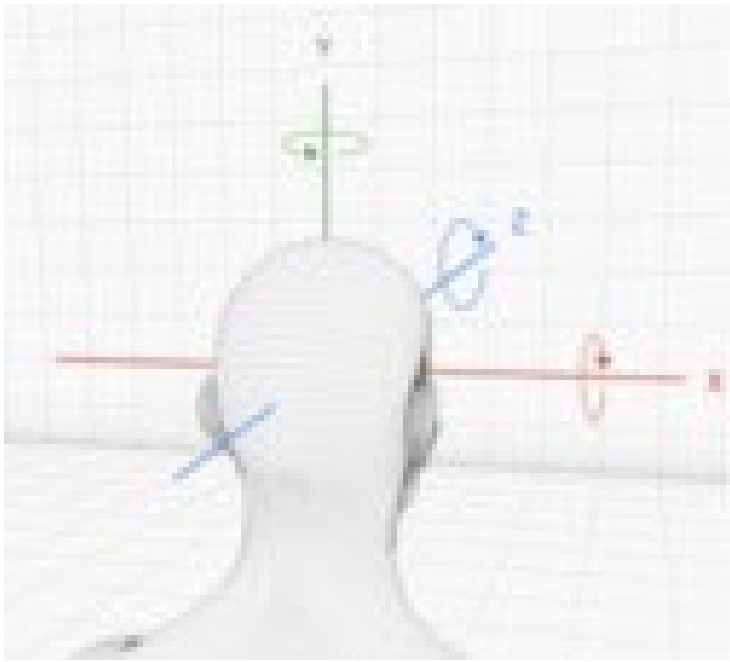

Figure 3. *Head Movement Axes*

habitual manner for fifteen minutes. They were instructed that breaks or pauses were allowed if they felt like they wanted to stop reading for any reason (e.g., fatigue, restroom breaks, etc.). After time began, the examiner exited the room and took observation notes from a small glass window. The participant was unable to see the examiner throughout the fifteen minutes. The webcam used was small, thus being minimally invasive and allowing the reading environment to remain similar to a child's habitual classroom reading environment. The goal of the procedure was to keep the reading environment as similar to their habitual classroom reading environment as possible.

Data Analysis

Head movement behaviors, vision screening results, and a teacher observation checklist filled out by the classroom teacher were all analyzed using the SPSS statistical software (Appendix A). The head movements of each study participant were recorded as 12 measurements: average position in meters on the x, y, and z axes; average rotation in degrees about the x, y, and z axes; standard deviations for x, y, and z positions; and standard deviations for rotation about x, y, and z axes (Figure 3). Two parts of the vision screening data, whether they passed or failed the screening, and their refractive error were analyzed for each student. Pass/fail was determined by the optometrist present at the vision screening and was based on the Pacific University Outreach Program's criteria.[+] The teacher observation checklist consists of 33 questions regarding behaviors a teacher can observe in a classroom and was created at Pacific University College of Optometry. The teacher ranks each of the questions on a scale of 0 to 4 (0=never, 1=seldom, 2=occasionally, 3=frequently, 4=always). Using the Principal Component Analysis method in addition to Equamax with Kaiser Normalization, a rotated component matrix was created for the 33 questions. Correlations between the questions enabled us to group them into five underlying components. These components were labeled based on what questions fell into the component. The labels were Reading Difficulty, Withdrawn, Head Behavior, Vision Quality, and Compensatory Behaviors. Additionally, the teacher could indicate whether the student was at, above, or below grade level in the areas of reading, spelling, handwriting, math, and science. Performing significantly below grade level was considered an exclusion criterion. Overall, the data were analyzed to answer the key questions: were head movement behaviors different between students who passed versus students who failed the vision screening, were they different between students with different refractive errors, and were there any correlations between the head movement behaviors and the underlying components of the teacher observation checklist?

+ Pacific University's vision screening criteria for passing a vision screening: visual acuities no worse than 20/30 (OD, OS, OU), stereoacuity no worse than 40 arc seconds, and no abnormalities on cover test, health, convergence ability, or refraction

Table 1: Difference in Means of Head Movements Between Students who Passed (n=9) and Students who Failed (n=15) the Vision Screening

		Levene's Test for Equality of Variances		t-test for Equality of Means							
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference		Effect Size
									Lower	Upper	
SDposx	Equal variances assumed	1.829	0.19	1.016	22	0.32	0.008	0.007	-0.008	0.023	0.49
	Equal variances not assumed			1.203	21.128	0.242	0.008	0.006	-0.005	0.020	
SDposy	Equal variances assumed	0.095	0.761	-1.065	22	0.299	-0.005	0.005	-0.014	0.005	-0.44
	Equal variances not assumed			-0.997	13.782	0.336	-0.005	0.005	-0.015	0.006	
SDposz	Equal variances assumed	3.295	0.083	0.369	22	0.716	0.007	0.019	-0.033	0.047	0.17
	Equal variances not assumed			0.423	21.96	0.676	0.007	0.017	-0.028	0.042	
SDrotx	Equal variances assumed	0.572	0.458	0.566	22	0.577	0.955	1.687	-2.544	4.454	0.24
	Equal variances not assumed			0.589	19.075	0.563	0.955	1.622	-2.440	4.350	
SDroty	Equal variances assumed	0.273	0.606	0.895	22	0.381	1.778	1.987	-2.343	5.900	0.43
	Equal variances not assumed			1.05	21.445	0.305	1.778	1.693	-1.739	5.295	
SDrotz	Equal variances assumed	3.028	0.096	1.177	22	0.252	1.266	1.075	-0.964	3.496	0.54
	Equal variances not assumed			1.321	21.922	0.2	1.266	0.958	-0.722	3.254	
AVGposx	Equal variances assumed	0.29	0.596	-1.918	22	0.068	-0.027	0.014	-0.057	0.002	-0.79
	Equal variances not assumed			-1.796	13.769	0.094	-0.027	0.015	-0.060	0.005	
AVGposy	Equal variances assumed	3.584	0.072	-0.79	22	0.438	-0.011	0.013	-0.038	0.017	-0.37
	Equal variances not assumed			-0.909	21.932	0.373	-0.011	0.012	-0.035	0.014	
AVGposz	Equal variances assumed	6.048	0.022	0.466	22	0.646	0.015	0.031	-0.050	0.080	0.19
	Equal variances not assumed			0.4	10.634	0.697	0.015	0.036	-0.066	0.095	
AVGrotx	Equal variances assumed	0.064	0.803	-1.212	22	0.238	-4.484	3.699	-12.155	3.187	-0.52
	Equal variances not assumed			-1.233	17.874	0.234	-4.484	3.638	-12.132	3.163	
AVGroty	Equal variances assumed	0.502	0.486	-0.513	22	0.613	-1.551	3.024	-7.824	4.721	-0.22
	Equal variances not assumed			-0.536	19.35	0.598	-1.551	2.893	-7.599	4.497	
AVGrotz	Equal variances assumed	0.076	0.786	1.019	22	0.319	1.933	1.898	-2.003	5.870	0.42
	Equal variances not assumed			0.991	15.575	0.337	1.933	1.951	-2.211	6.078	
Reading Difficulty	Equal variances assumed	0.175	0.68	0.124	22	0.903	0.053	0.431	-0.840	0.947	0.05
	Equal variances not assumed			0.133	20.788	0.895	0.053	0.400	-0.779	0.885	
Withdrawn	Equal variances assumed	2.844	0.106	-2.764	22	0.011	-1.026	0.371	-1.797	-0.256	-1.12
	Equal variances not assumed			-2.487	12.187	0.028	-1.026	0.413	-1.924	-0.129	
Head behavior	Equal variances assumed	2.436	0.133	1.04	22	0.31	0.438	0.421	-0.435	1.311	0.50
	Equal variances not assumed			1.215	21.596	0.237	0.438	0.360	-0.310	1.186	
Vision Quality	Equal variances assumed	1.777	0.196	-0.615	22	0.545	-0.263	0.427	-1.149	0.624	-0.25
	Equal variances not assumed			-0.546	11.731	0.595	-0.263	0.481	-1.314	0.788	
Compensatory Behavior	Equal variances assumed	0.618	0.44	0.164	22	0.871	0.071	0.431	-0.823	0.964	0.07
	Equal variances not assumed			0.177	20.65	0.862	0.071	0.401	-0.764	0.906	

The head movements of each study participant were recorded as 12 measurements: average position in meters on the x, y, and z axes (AVGposx,y,z); average rotation in degrees about the x, y, and z axes (AVGrotx,y,z); standard deviations for x, y, and z positions (STDposx-,y,z); and standard deviations for rotation about x, y, and z (STrotx,y,z).

An independent samples t test was done to compare the means of the 12 head movements of the students who passed the vision screening and the students who failed. The same test was done to compare the means of the 12 head movements of the hyperopic students and the myopic students. Additionally, a Pearson correlation was used to determine whether a linear relationship was present between any of the 5 components of

Table 2: Difference in Means of Head Movements Between Hyperopes (n=13) and Myopes (n=8)

		Levene's Test for Equality of Variances		t-test for Equality of Means							
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference		Effect Size
									Lower	Upper	
SDposx	Equal variances assumed	0.087	0.771	0.86	19	0.401	0.007	0.008	-0.010	0.024	0.407
	Equal variances not assumed			0.929	18.328	0.365	0.007	0.008	-0.009	0.023	
SDposy	Equal variances assumed	1.026	0.324	1.571	19	0.133	0.008	0.005	-0.003	0.018	0.765
	Equal variances not assumed			1.752	18.963	0.096	0.008	0.004	-0.002	0.017	
SDposz	Equal variances assumed	0.003	0.96	1.202	19	0.244	0.025	0.020	-0.018	0.067	0.542
	Equal variances not assumed			1.21	15.288	0.245	0.025	0.020	-0.019	0.068	
SDrotx	Equal variances assumed	0.06	0.808	-0.082	19	0.936	-0.15	1.84	-4.01	3.71	-0.04
	Equal variances not assumed			-0.083	15.469	0.935	-0.15	1.82	-4.03	3.72	
SDroty	Equal variances assumed	0.509	0.484	1.153	19	0.263	2.51	2.17	-2.04	7.05	0.60
	Equal variances not assumed			1.354	18.119	0.192	2.51	1.85	-1.38	6.39	
SDrotz	Equal variances assumed	2.785	0.112	-0.246	19	0.808	-0.30	1.20	-2.81	2.22	-0.11
	Equal variances not assumed			-0.226	11.346	0.825	-0.30	1.31	-3.16	2.57	
AVGposx	Equal variances assumed	0.051	0.824	0.251	19	0.804	0.00	0.01	-0.03	0.03	0.12
	Equal variances not assumed			0.268	17.86	0.792	0.00	0.01	-0.03	0.03	
AVGposy	Equal variances assumed	0.42	0.525	1.431	19	0.169	0.02	0.01	-0.01	0.05	0.67
	Equal variances not assumed			1.526	17.862	0.144	0.02	0.01	-0.01	0.05	
AVGposz	Equal variances assumed	1.831	0.192	-0.383	19	0.706	-0.01	0.03	-0.08	0.05	-0.18
	Equal variances not assumed			-0.413	18.329	0.684	-0.01	0.03	-0.07	0.05	
AVGrotx	Equal variances assumed	1.293	0.27	1.906	19	0.072	7.21	3.78	-0.71	15.12	0.83
	Equal variances not assumed			1.766	11.643	0.104	7.21	4.08	-1.71	16.13	
AVGroty	Equal variances assumed	0.055	0.817	-1.035	19	0.314	-3.07	2.97	-9.29	3.14	-0.46
	Equal variances not assumed			-0.991	12.98	0.34	-3.07	3.10	-9.77	3.63	
AVGrotz	Equal variances assumed	0.053	0.82	-1.101	19	0.285	-2.36	2.15	-6.86	2.13	-0.49
	Equal variances not assumed			-1.055	13.006	0.311	-2.36	2.24	-7.21	2.48	
Reading Difficulty	Equal variances assumed	0.022	0.884	0.355	19	0.726	0.17	0.48	-0.83	1.17	0.16
	Equal variances not assumed			0.33	11.754	0.747	0.17	0.51	-0.95	1.29	
Withdrawn	Equal variances assumed	4.566	0.046	1.695	19	0.106	0.64	0.38	-0.15	1.44	0.88
	Equal variances not assumed			1.992	18.11	0.062	0.64	0.32	-0.04	1.32	
Head behavior	Equal variances assumed	0.058	0.811	0.427	19	0.674	0.21	0.48	-0.80	1.22	0.19
	Equal variances not assumed			0.421	14.256	0.68	0.21	0.49	-0.84	1.26	
Vision Quality	Equal variances assumed	8.188	0.01	1.43	19	0.169	0.66	0.46	-0.31	1.63	0.80
	Equal variances not assumed			1.759	15.401	0.098	0.66	0.38	-0.14	1.46	
Compensatory Behavior	Equal variances assumed	0.028	0.868	-0.328	19	0.747	-0.15	0.46	-1.11	0.81	-0.15
	Equal variances not assumed			-0.342	16.967	0.737	-0.15	0.44	-1.08	0.78	

the teacher observation checklist and the 12 head movement measurements.

Results

The Levene's Test for Equality of Variances shows no significance, thus the Equal Variance assumed output in Table 1 was used. With p-values all larger than our chosen significance level of 0.05, the results indicate no significant difference between the means of head movements for participants who failed and who passed the vision screening. Therefore, we cannot say that head movement behaviors are significantly different between subjects who pass versus subjects who fail the vision screenings. No significant difference

Table 3: Possible Linear Relationships Between Head Movement Measurements and the Components of the Teacher Observation Checklist or the Student's OU Spherical Equivalent.

		SDposx	SDposy	SDposz	SDrotx	SDroty	SDrotz	AVGposx	AVGposy	AVGposz	AVGrotx	AVGroty	AVGrotz
Reading Difficulty	Pearson Correlation	-0.134	-0.066	0.012	-0.218	0.608**	-0.226	0.226	-0.405*	0.28	0.063	0.127	-0.438*
	Sig. (2-tailed)	0.532	0.758	0.957	0.307	0.002	0.288	0.289	0.05	0.185	0.769	0.555	0.032
Withdrawn	Pearson Correlation	-0.155	-0.112	0.004	-0.194	-0.117	-0.061	0.524**	0.354	0.172	0.267	-0.059	-0.132
	Sig. (2-tailed)	0.47	0.603	0.986	0.364	0.585	0.778	0.009	0.089	0.421	0.207	0.785	0.539
Head Behavior	Pearson Correlation	-0.004	-0.014	-0.01	0.017	-0.038	0.143	0.003	0.132	-0.103	0.037	-0.161	-0.062
	Sig. (2-tailed)	0.984	0.948	0.963	0.936	0.861	0.505	0.99	0.539	0.632	0.862	0.451	0.772
Vision Quality	Pearson Correlation	-0.106	0.129	0.145	0.227	-0.143	0.081	-0.17	-0.043	0.174	0.244	-0.182	-0.034
	Sig. (2-tailed)	0.621	0.548	0.498	0.287	0.505	0.708	0.428	0.843	0.415	0.25	0.394	0.876
Compensatory Behavior	Pearson Correlation	-0.012	0.211	.422*	0.09	0.218	0.191	-0.29	0.006	-0.111	0.113	0.048	0.017
	Sig. (2-tailed)	0.954	0.322	0.04	0.676	0.306	0.37	0.17	0.979	0.604	0.601	0.824	0.938
OUSphEq	Pearson Correlation	0.044	0.258	0.304	0.077	0.078	0.025	0.005	-0.131	0.102	0.363	-0.17	-0.191

**Correlation is significant at the 0.01 level (2-tailed). *Correlation is significant at the 0.05 level (2-tailed).

exist between the means of head movements for hyperopic and myopic participants was found (Table 2).

In addition to the Levene's test, effect sizes (ES) were calculated. Effect size was used to analyze the size of the difference in means without confounding it with the sample size. Between participants who passed and who failed the screening, effect sizes were large for the standard deviations of position on the x and y axes (ES=0.49, ES=-0.44), standard deviations of rotation around the y and z axes (ES=0.43, ES=0.54), average positions on the x axis (ES=-0.79), average rotations around the x and z axes (ES=-0.52, ES=0.42), and questions on the teacher observation checklist under the Withdrawn and Head Behavior components (ES=-1.12, ES=0.50). Additionally, between hyperopes and myopes, effect sizes were large for the standard deviations of position around the x, y, and z axes (ES=0.407, ES=0.765, ES=0.542), the standard deviation of rotation around the y axis (ES=0.60), the average position on the y axis (ES=0.67), the average rotation around the x, y, and z axes (ES=0.83, ES=-0.46, ES=-0.49), and questions on the teacher observation checklist under the Withdrawn and Vision Quality components (ES=0.88, ES=0.80).

As illustrated in Table 3, a few of the underlying components from the Teacher Observation Checklist showed a positive linear relationship with head movement behaviors in the x and y axes. With a sample size of 24 and no obvious pattern, these positive correlations may be due to chance. However, for a pilot study, these positive correlations in combination with effect sizes larger than 0.3 suggest that this study deserves further investigation.

Discussion

Previous research revealed relationships between visual functions and reading performance in children.[24,25] Based on those findings, optometry created and distributed checklists of signs/symptoms for which parents and teachers should watch that may indicate that a child needs a vision examination. Those checklists include head movement behaviors such as head tilt, holding one's head closer or further from reading material, and overall excessive head movements during reading. Finding only limited literature on head

Table 4. Means of Standard Deviations of Head Movements of Subjects Who Failed the Vision Screening Compared to Subjects Who Passed. Refer to Fig 3 for definition of x, y, & z axes.

	Failed Means (meters)	Passed Means (meters)
SDposx	0.035	0.027
SDposy	0.024	0.029
SDposz	0.089	0.082
	Failed Means (degrees)	Passed Means (degrees)
SDrotx	9.292	8.337
SDroty	10.097	8.319
SDrotz	6.389	5.123

movements while reading in correlation to a child's visual system, this study aimed to probe the head movement items on these checklists further.

Our results showed that the mean values of head movements for students who passed versus students who failed the vision screenings were not different. Additionally, the means for students with hyperopia were not statistically different than students with myopia. As a result of having a small sample size, we cannot say whether the Pearson correlation results indicated that head movements while reading are significantly associated with either the vision screening results or any questions on the teacher observation checklist, or whether they are due to random chance.

This study was designed as a pilot study; therefore, we wanted to supplement the statistical results with qualitative observations and interpretations of the data in order to inform possible future studies better. Although the means in Table 4 are not statistically different (using Levene's test) between subjects who passed and who failed, there is a trend. A high standard deviation for a head position measurement indicates that the subject spent more time with the head moving away from the straight-ahead, stationary position. Except for the mean of the standard deviation of head position on the y axis (SDposy), all of the other means are higher for the subjects who failed the vision screening than for the subjects who passed. Although the means are not statistically different, this finding is interesting since the researcher subjectively noted that some subjects moved their heads more drastically and more often than other subjects. Based on this possible trend, we believe that our initial question, "Are head movement behaviors different between students who passed versus students who failed the vision screening?" may merit further investigation. Possibly, subjects with visual functions resulting in failure of the vision screening can be detected based on more head movements while reading.

Trends for head movement behaviors of subjects with different refractive errors were also considered. Means for head rotation around the y axis (turning head away left or right) were compared for hyperopes and myopes and showed that hyperopes had a higher standard deviation for rotation than myopes (hyperopes=10.675, myopes=8.170). These means are not statistically different, but they may reveal a trend that hyperopes turn their heads left or right, or away from the reading material, more often than myopes.

Subjective observation was performed without the observer knowing the refractive errors of the subjects. These observation notes consisted of subjective descriptions of head stability and movement away from straight ahead. After matching the subjective observation notes with the subject's refractive errors, a pattern showed that subjects with larger refractive errors had more head movement variability. Therefore, we ran a post-hoc Pearson correlation, this time splitting data into two categories: refractive errors and emmetropes. Emmetropia was defined as the spherical equivalent of the right eye between -0.25 and +0.50 diopters. Anything outside of emmetropia was categorized as a refractive error (emmetropes: n=14, refractive errors, n=10). We calculated the Pearson product-moment correlation coefficient between spherical equivalents OD and mean

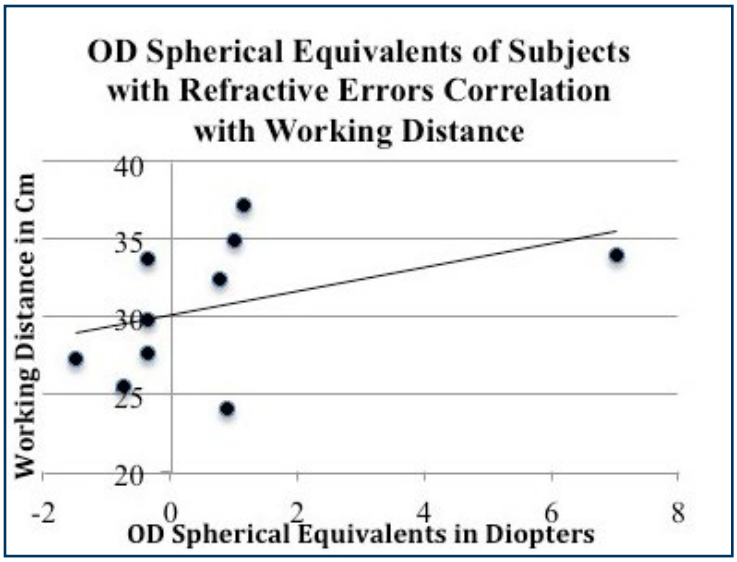

Figure 4. *Correlation between OD spherical equivalents of subjects with refractive errors and working distance from reading material*

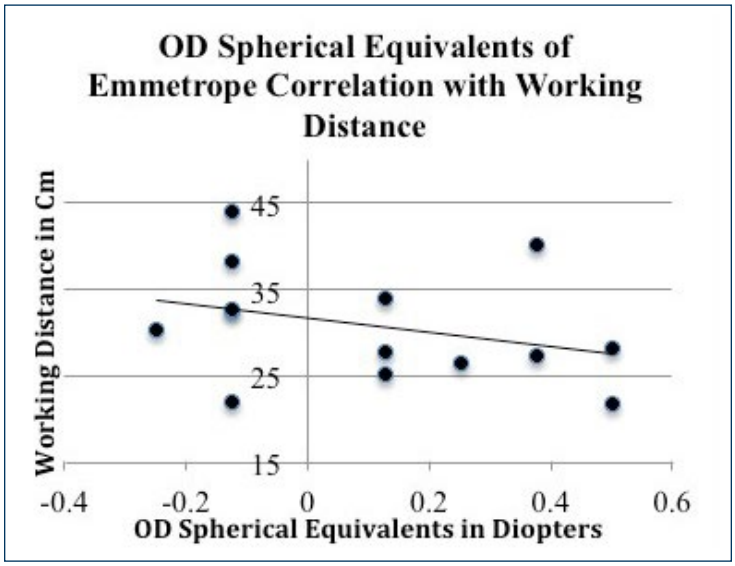

Figure 5. *Correlation between OD spherical equivalents of emmetropic subjects and working distance from reading material*

working distances from the reading material (position on the z axis). As seen in Figures 4 and 5, refractive errors had a positive correlation with working distance (coefficient=0.4218), and emmetropia had a negative correlation with working distance (coefficient=-0.3166). However, the correlation for emmetropes was closer to zero. A positive correlation implies that as refractive error becomes more positive (hyperopic), working distance increases, and as refractive error becomes more negative (myopic), working distance decreases. This may indicate that more studies looking at the correlation between working distance and refractive error may prove useful.

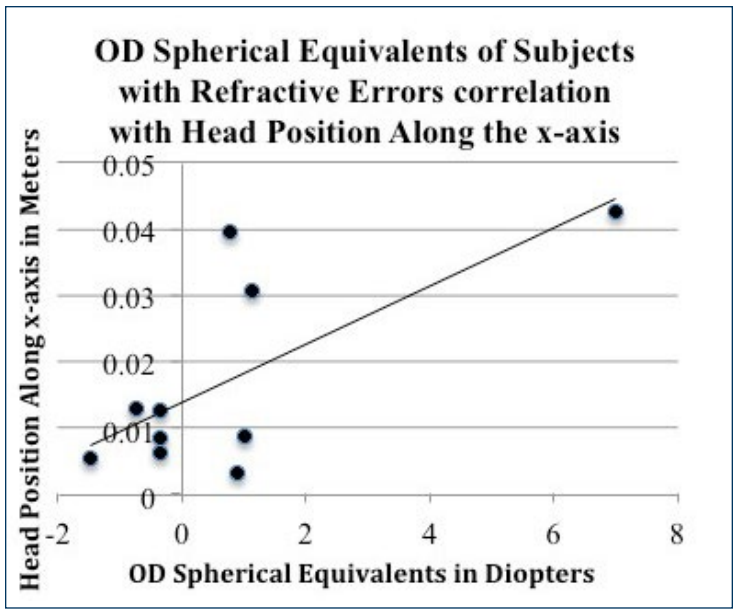

Figure 6. *Correlation between OD spherical equivalents of subjects with refractive errors and head positions along the x-axis*

The Pearson correlation coefficient between spherical equivalents OD and mean position on the x axis (head positioned left or right from center) was 0.6978 for subjects with refractive errors but showed no correlation for emmetropes (Figure 6). It did not matter whether the subject's head moved to the left or to the right, only the amount of head movement mattered. Therefore, this correlation was calculated with the absolute values of the means of head positions along the x axis. This correlation demonstrates that an increase in hyperopia correlates with an increase in head movement on the x axis, and an increase in myopia correlates with a decrease in head movement along the same axis.

Follow-up Pearson correlation tests showed some possible correlations between refractive errors and head movements while reading. However, due to the small sample size, these are not considered statistically reliable. As a pilot study, we believe that these are intriguing trends that encourage us to explore further research in the area of head movements during reading as an indication of the status of a child's visual system. Based on previous research about refractive errors and working distance, and the trends found in this study, this topic merits further research.26-28

Additionally, based on subjective observations and data trends in this study, we strongly believe that more studies regarding head movements as a sign of visual dysfunction in children should be done. During this study, we found that it was difficult to make objective head movement measurements on children while also keeping their reading environment habitual. Therefore, the lack of literature in the area of head movements while reading and a child's visual system may be in part due to the difficulty of analyzing such behaviors objectively and habitually at the same time, or alternatively, because no such correlation is present when a larger sample size is evaluated.

Conclusion

Based on our results, we cannot statistically validate the head movement behaviors listed on the optometry checklists currently in circulation. We believe that our results do provide evidence that these claims deserve further exploration. We also feel that this study subjectively demonstrated the importance of teachers in detecting these early signs of visual problems. Therefore, if further research is to take place in this area, teacher input on head movements should again be taken into consideration.

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PACIFIC UNIVERSITY
FAMILY VISION CENTER

I authorize the release of this information to Pacific University Family Vision Center

_____
Parent's Signature Date

TEACHER OBSERVATION CHECKLIST

The parents of _____ have granted us permission to request the following information from you, which may be associated with the vision and/or visual, perceptual, or attention difficulties.

All information you provide will be held in confidence. Please check the most appropriate box, or circle the item number that best represents your observations. The form requires 5-min. to complete. Thank you for your help!

How well do you know this student? **not at all** ⇒ 1 2 3 4 5 6 7 8 9 ⇐ **very well**
Could academic performance be better than present? **yes** ⇒ 1 2 3 4 5 6 7 8 9 ⇐ **no**

Please rate each of the following behaviors for frequency of occurrence	Never	Seldom	Occasionally	Frequently	Always	Don't Know
Complains of blurred vision	0	1	2	3	4	
Complains of double vision/overlapping words on a page	0	1	2	3	4	
Rubs or blinks eyes excessively	0	1	2	3	4	
Frowns or squints during near visual tasks	0	1	2	3	4	
Complains of eye discomfort/soreness/redness	0	1	2	3	4	
Covers or closes one eye for near tasks	0	1	2	3	4	
Tends to hold reading excessively close	0	1	2	3	4	
Tilts or twists head when doing visual work	0	1	2	3	4	
Complains of headaches/dizziness following visual tasks	0	1	2	3	4	
Skips/rereads words/sentences/loses place when reading	0	1	2	3	4	
Moves head excessively when reading	0	1	2	3	4	
Uses finger for marker when reading	0	1	2	3	4	
Misaligns digits or columns of numbers	0	1	2	3	4	
Poor handwriting (spacing, size, legibility)	0	1	2	3	4	
Slowness or many errors when copying from whiteboard	0	1	2	3	4	
Problems with eye-hand coordination	0	1	2	3	4	
General body coordination problems/clumsiness	0	1	2	3	4	
Inconsistent sports performance	0	1	2	3	4	
Difficulty learning new words/Inadequate sight vocabulary	0	1	2	3	4	

Poor phonetic decoding skills	0	1	2	3	4	
Poor reading fluency	0	1	2	3	4	
Poor reading comprehension	0	1	2	3	4	
Confuses letters or words	0	1	2	3	4	
Reverses letters or words	0	1	2	3	4	
Short attention span/easily distracted	0	1	2	3	4	
Forgetful/loses belongings/poor memory	0	1	2	3	4	
Off-task, disruptive behavior, hyperactivity	0	1	2	3	4	
Difficulty completing assignments on time	0	1	2	3	4	
First response is: "I can't" before trying	0	1	2	3	4	
Aggressive	0	1	2	3	4	
Withdrawn	0	1	2	3	4	
Low energy/tires easily/falls asleep when reading	0	1	2	3	4	
Poor self esteem	0	1	2	3	4	

Please describe other areas that may concern you about this child's learning style, abilities, or achievement:

How is this student performing academically? (Please check the most appropriate box)

	At grade level	Above grade level	Below grade level
Reading			
Spelling			
Handwriting			
Math			
Science			

Child's current grade level: _____. Has this child had any formal assessment for learning difficulties: _____? How recently: _____? Is this student currently on an Individualized Education Plan or Section 504 Plan for identified disability: _____? If so, what specific areas: _____?

Thank you for assisting us in providing optimal visual care for this child. We appreciate you taking the time to provide us with a record of your observations. Please return this form in the enclosed envelope.

Teacher signature:_____

Printed name_____ **Grade/class:** _____

School name & address:_____

If you would like informational materials about any of the vision care topics below mailed to you, please check:

_____ Vision-Related Learning Difficulty _____ Vision Therapy _____ Infants' Vision
_____ Vision Enhancement _____ Preventive Vision Care _____ Sports Vision