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Visual Impairment and Reading Ability in High and Low Socioeconomic Status Children with a Unilateral Congenital Cataract

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2014

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An abstract of

A thesis submitted to the Faculty of the
Rollins School of Public Health of Emory University

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Master of Public Health
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Abstract:

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By Jennifer Momkus

Background: Even with treatment, children born with a unilateral congenital cataract (UCC) often have poor vision in the affected eye. It is important to understand the functional impact of this unilateral impaired vision to inform clinical decision-making. We examined the association between visual impairment (VI) in the affected eye with reading ability to understand how UCC affects learning. We also investigated if this association differs based on socioeconomic status (SES).
Methods: A cohort of children who received treatment for UCC in early infancy were followed throughout childhood. At age 10 ½ years, visual acuity was ascertained, and reading rate and eye movements during silent reading were assessed using a ReadAlyzer. We compared distributions of reading rates, proportion of and number of regressive saccades while reading between three categories of visual acuity in the affected eye; near normal (20/40 or better), mild-moderate VI (20/40 to 20/200), and severe VI (20/200 or worse). We performed a linear and logistic regression with reading as a function of visual acuity controlling for relevant confounders. We also examined the possibility of interaction by insurance status (public vs. private) as a proxy for SES.
Results: After controlling for covariates, there was no significant difference in the average reading rate (near normal=158wpm, mild to moderate VI=173wpm, 1 severe VI=158wpm, p=0.70), number of regressive saccades (near normal=38, mild to moderate VI=28, severe VI=43, p=0.29), or the average regressive saccade to fixation ratio (near normal=22%, mild to moderate VI=18%, severe VI=22%, p=0.36) between the three visual acuity categories. However, the odds of poor reading outcomes among those with severe VI differed meaningfully by socioeconomic status (low SES: $OR_{slow\ reading}$=2.26, 95% CI [0.45, 11.26], $OR_{high\#\ regr\ saccades}$=3.54, 95% CI [0.72, 17.32], $OR_{high\ regr/fixation\ ratio}$=3.61 [0.74,17.66] vs. high SES: $OR_{slow\ reading}$=0.48, 95% CI [0.12, 2.02], $OR_{high\#\ regr\ saccades}$=0.93, 95% CI [0.21, 4.22], $OR_{high\ regr/fixation\ ratio}$=0.35 [0.07, 1.82])
Conclusions: There did not appear to be a significant benefit of better visual outcomes on silent reading in 10-year old children treated for UCC. However, socioeconomic status is associated with poorer reading and poor vision in the treated eye may exacerbate this concern.

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Introduction

Unilateral Congenital Cataract (UCC) is a challenging condition for pediatric ophthalmologists. Even with early detection and a labor-intensive treatment, visual function often does not reach normal levels (1-3). In addition, even if treatment results in good vision in the affected eye, UCC usually results in a deep deprivation amblyopia because of unilateral vision deprivation and required occlusion therapy to try to achieve good visual outcomes in the affected eye. Thus, those treating and caring for children with a UCC must consider the life-long impacts of amblyopia visual impairment in the affected eye.

Despite the long-lasting effects on visual acuity, the impact of deprivation amblyopia on real-world functioning is still not fully understood, and deprivation amblyopia is under-studied relative to other, more common types of amblyopia such as resulting from strabismus and/or anisometropia (4). Strabismic and aniosommetropic amblyopia have been found to be associated with decreased fine and gross motor skills (5) and child self-perception (6) in some studies. Other studies have suggested vision impairment affects learning development (7). However, evidence is conflicting with some studies suggesting amblyopia affects neither motor development nor self-esteem (8, 9). Given the permanent nature of amblyopia and UCC specifically, it is necessary to better understand the functional impact of improved visual outcomes in the treated eye to improve clinical decision-making.

One important functional area highly dependent on vision is reading. Poor reading skills in elementary school are associated with detrimental educational outcomes (10). Furthermore, academic success and reading in elementary school predict long-term academic achievement, economic success, and overall life satisfaction (11, 12). Studies have suggested children with amblyopia read more slowly compared to children with normal bilateral vision (13, 14). However, most studies have not included children with deprivation amblyopia, nor have these studies considered the impact of the degree of residual visual acuity in amblyopic individuals on binocular reading skills. Consequently, it is unclear if visual acuity itself plays a role or if the difference can be attributed to oculomotor function.

It has been well-established that childhood socioeconomic status (SES) affects the development of reading. Many researchers have found a relationship between higher childhood SES and better reading ability (15-20). Though research on amblyopia has employed adult SES-related measures as outcomes of interest (8, 21, 22), there have been few studies examining how the effects of amblyopia on reading differ by childhood SES. It is important to understand how childhood SES could play a role in the relationship between of vision impairment and reading ability in amblyopic children to prevent the exacerbation of educational and health disparities.

To understand how poor vision in children born with a unilateral congenital cataract (UCC) may affect their reading abilities, we examined the association between vision impairment in the affected eye and reading in children at age 10½. First, we investigated if there was a difference in reading rates between children with near normal vision, mild to moderate vision impairment (VI), and severe VI in the affected eye. We also considered potential differences in reading efficiency by examining if children with severe vision impairment in the affected eye have more regressive saccades (backward eye movements) or a higher regressive saccade to fixation ratio (the percentage of times the eyes look backwards out of all the times eye movements stop going forward) when reading compared to children with normal vision. Lastly, we investigated the possibility of effect modification by socioeconomic status on vision impairment in the affected eye with reading speed and efficiency.

Methods

Study Design and Population

We examined cross-sectional data from the cohort of infants who previously participated in the Infant Aphakia Treatment Study (IATS). This study has been described elsewhere in detail (23). Briefly, it was a randomized, multicenter (n = 12) clinical trial of infants surgically treated for unilateral congenital cataract (UCC) comparing primary intraocular lens (IOL) implantation to contact lens correction. The participating clinical centers were academic medical centers in states across the U.S. The sites included were: Medical University of South Carolina (14 participants), Harvard University (14 participants), University of Minnesota (13 participants), Cleveland Clinic (10 participants), Baylor University (10 participants), Oregon Health and Science University (9 participants), Emory University (9 participants), Duke University (8 participants), Vanderbilt University (8 participants), Indiana University (7 participants), Miami Children's Hospital (6 participants), and University of Texas Southwestern (6 participants) .

Inclusion criteria included a congenital cataract > 3 mm central opacity in one eye and age between 28 to 210 days at the time of surgery. Patients who were born premature (<36 weeks gestational age) were excluded. Other exclusion criteria included an acquired cataract, corneal diameter < 9 mm, a persistence of the fetal vasculature (PFV) associated with visible stretching of the ciliary processes, involvement of the retina, or involvement of the optic nerve. Exclusion criteria relating to evaluation of the eye were determined by the treating IATS investigator. Patients were randomized during the surgery to have the IOL implanted or have the eye be left aphakic. After cataract surgery, participants (n=114) were followed quarterly until age 5, and then in a single clinic visit at age 10 ½ years. Of the 114 participants randomized, 109 were seen at age 10 ½ (96%).

Visual Acuity

At age 10 ½, best-corrected visual acuity (VA) in both eyes was measured using the E-ETDRS testing protocol (24). Children who were assigned a contact lens wore their current contact lens in the assessment. Any remaining refractive error was corrected with trial frames. Children wore their aphakic correction in trial frames for the assessment if they were randomized to contact lens correction but had subsequently stopped wearing the contact lens and did not receive a secondary IOL. Children who had been assigned an IOL were tested wearing their cycloplegic refraction in trial frames. Binocular vision was assessed first, then vision in each eye separately. Monocular vision was initially tested in the treated eye, then in the untreated eye. The initial testing distance was 3 meters, but if a child was unable to see a 20/800 letter at 3 meters the distance was decreased to 1 meter. If a child was unable to see a 20/800 letter at 1 meter, then the tester proceeded to test for hand motion at 0.66 meters. If the child could not detect hand motion, then the eye was assessed for light perception (25). Monocular visual acuity in the treated eye was used for these analyses.

Reading

Data on silent reading were collected using the ReadAlyzer® system (Compevo AB, Stockholm, Sweden) by study staff at the clinic visit at age 10 ½ years. The ReadAlyzer is an infrared eye movement recording system placed in googles that can be worn over the child's regular spectacle correction. While wearing the ReadAlyzer, each child sat eye level at a comfortable reading distance of around 35-40cam and read three short passages of increasing difficulty: 1st grade, 3rd grade, and current grade level. The grade level 1 passage was used as practice to ensure that the goggles were tracking correctly. If there was an issue with the positioning of the goggles, they were adjusted and tested again before proceeding to the grade level 3 passage. Measures from the ReadAlyzer include reading rate (words per minute [wpm]), total number of regressive saccades, and ratio of regressive saccades to fixation (i.e. the proportion of times the child looks back every time they stop reading). Those in the bottom quartile of reading rates were considered to be slower readers. Those who were in the top quartile of the number of regressive saccades or regressive to fixation ratio were considered to be inefficient readers.

Covariates such as sex and race were obtained via parent report. The assignment of primary IOL implantation or contact lens correction for the UCC was not included as a covariate since it was found to have no long-term effect on vision (26). Insurance status (private vs. public) was known from the previous medical treatment in the randomized trial. If private insurance was available, the child was classified as high SES. Otherwise, they were designated as low SES. This study was approved by the institutional review boards of all the participating institutions.

Statistical Methods

Participants were classified into three exposure categories based on visual acuity of the affected eye at age 10 ½ years: near normal (VA≤20/40), mild to moderate vision impairment (20/40≤VA≤20/200) and severe vision impairment (VA> 20/200). Analyses of Variance (ANOVA) were used to investigate if the degree of unilateral vision impairment affected reading outcomes in reading a passage written at the 3rd grade level. In addition, a two-sample t-test was used to determine if there was a difference in the average reading outcomes of children with severe VI (VA>20/200) compared to children with near normal vision to moderate VI in the treated eye (VA≤20/200). To estimate the differences in reading outcomes between each level of vision impairment while adjusting for potential confounders, we completed a multivariable linear regression with logMAR VA in the treated eye as the exposure variable and reading rate, number of regressive saccades, and regression/fixation ratio of the 3rd grade-level passage as the outcomes. Sex, race, VA in the fellow eye and SES were included as predictors.

To understand if the prevalence of slower and/or less efficient reading was higher in those with severe VI in the affected eye compared to those with near normal, mild, and moderate VI combined, we conducted a logistic regression controlling for sex, race, VA in the fellow eye, and SES. To examine the possibility of effect modification of the relationship between VA and reading rate by SES, we also performed a multivariable logistic regression including the previously mentioned covariates and an interaction term between the dichotomous VA variable (severe VI vs. all others) and SES (private vs. public insurance). To investigate if there was an overall difference in reading outcomes by SES, two-sample t-tests were performed for each reading outcome stratified by insurance status.

Results

There were 114 children enrolled in IATS. 109 were followed to age 10 ½ (96%). Ten subjects did not have any reading data available because of equipment failures. Five reading assessments could not be used as the ReadAlyzer could not achieve reliable results. One subject had incorrectly recorded data. One additional subject with Stickler's Syndrome was not included in the analysis because the fellow eye had poor visual acuity. There were 92 subjects with complete data available. Demographic characteristics are available in Table 1. The population was largely white with private insurance. Most children were currently in grade 4 or 5. Different visual acuity categories were comparable on most demographic variables except there tended to be more children without private insurance in the severe visual impairment category. Among those with public insurance, about 12% had near normal visual acuity, 32% had mild to moderate vision impairment, and 56% had severe VI (Table 1). On average, higher SES children consistently had better reading outcomes (Table 2), though the only statistically significant difference was for the regressive to fixation ratio ($\mu_{highSES}$=18.4% vs. μ_{lowSES}= 24.6% for lower SES children, p=0.03) (Table 2).

All children were able to read and comprehend (>80%) the first grade and third grade level passages. The summary statistics for each reading outcome are shown in Table 3. There were minor differences in the average silent reading outcomes (reading rate p=0.70; number of regressive saccades p=0.29, regression/fixation ratio p=0.36) (Table 3, Figure 1-3). LogMAR visual acuity was not associated any of the reading outcomes ($\beta_{Reading\ Rate}$= -12.9, p=0.37; a$\beta_{Reading\ Rate}$= -10.4, p=0.50; $\beta_{\#Regressive\ Saccades}$= 9.1, p=0.22; a$\beta_{\#Regressive\ Saccades}$= 4.0, p=0.51; $\beta_{Regression/Fixation}$ =2.8, p=0.21; a$\beta_{Regression/Fixation}$

=0.82, p=0.73) (Table 4). There did not appear to be a strong association between severe vision impairment (compared to all others) and slower and/or inefficient reading overall (Table 5). The odds ratios were all relatively close to the null and all confidence intervals included the null (Table 5).

There was insufficient statistical power to suggest significant interaction between socioeconomic status and visual acuity in the affected eye, but there were noteworthy differences in the odds ratios stratified by the SES proxy variable. For example, among those without private insurance the odds of slow reading were more than 2 times higher among those with severe vision impairment in the treated eye than among those with better VA (Table 6). Conversely, among those with private insurance, the odds of slow reading were somewhat lower among those with better vision than among those with a severe vision impairment (Table 6). A similar pattern of meaningfully different odds ratios when stratified by SES were observed for inefficient reading as measured by the total number of regressive saccades and the regression/fixation ratio (Table 6). Due to the limited sample size, confidence intervals were wide and included the null for all reading outcomes

Discussion

In the present study, we were seeking to better understand how poor vision in children with a unilateral congenital cataract may affect their reading abilities. It is important to understand the functional impact of visual impairment in this population to inform clinical decision-making. We did not find that silent reading skills in 10 ½ year old children were significantly associated with the degree of vision impairment in children with deprivation amblyopia resulting from a UCC. These findings suggest that monocular reading, rather than the amount of residual vision, is likely contributing to observed differences in silent reading skills that have been observed in children with amblyopia as compared to children without visual impairments (27). However, we did observe that children without access to private insurance had poorer reading skills overall, and that poor visual outcomes exacerbate this effect.

A previous study showed amblyopic children with strabismus and/or anisometropia were slower at binocular silent reading when compared to normal control children (13). They also found the amblyopic eye visual acuity was not correlated with the reading rate or regressive saccades (among the amblyopic children). However, this group has reported that children with deprivation amblyopia from unilateral cataract do not read more slowly than children with normal binocular vision (28) suggesting that deprivation amblyopia may impact reading differently than strabismic and/or anisommetropic amblyopia. Deprivation amblyopia usually results in more severe unilateral vision impairment than other types of amblyopia (4, 29) and may have greater impacts on development of stereoacuity (30-32). The comparison to children without amblyopia could suggest amblyopia itself, regardless of level of vision impairment, affects reading. Another study found an increases in the number of forward saccades observed in amblyopic children compared to normal controls (33). The increase in forward saccades could suggest slower reading is due to oculomotor dysfunction, not vision impairment. In our study all children had amblyopia thus may have had similar oculomotor dysfunction regardless of the level of visual acuity in the treated eye. Neither of these studies examined differences in the effect based on socioeconomic status, so an effect only among lower SES children could have been missed.

We found no evidence to suggest that the degree of vision impairment in children treated for UCC impacts silent reading outcomes among elementary school-aged children. The large differences in the measures of association between those with and without private insurance demonstrate the possibility of effect modification by socioeconomic status on the relationship between unilateral vision impairment and reading ability. The effect of severe vision impairment in the treated eye could very well be more detrimental to reading ability for lower socioeconomic status children compared to high SES children.

Effect modification by socioeconomic status could occur through a number of pathways. In terms of more direct effects, those who are higher SES could have more tangible clinical or educational resources from family, healthcare providers, and schools to overcome barriers to reading development. Many studies have shown cognitive development is associated with early childhood social environments (34). Poverty has also been associated with treatment failure in children with amblyopia (35). Additionally, there may be more indirect mechanisms resulting from cumulative social exposures affecting both visual and academic development. For instance, a study in Canada showed that even though treatment was technically accessible to a cohort of children with amblyopia, children from the richest neighborhood were more likely to utilize treatment services (36).

Strengths and Weaknesses:

Our study had several strengths and limitations. First, long-term follow up of the cohort even after 10 years was excellent with a 96% follow-up rate and there was comprehensive data available for most subjects. We were also able to obtain a wider range of levels of visual impairment in our cohort than in previous studies of reading outcomes in school-aged children with amblyopia, allowing us to examine more significant unilateral impairments than have been included in most studies. However, there were no normal controls to compare children to in this study. The relatively small sample size limited the statistical power of our analyses particularly in our examination of potential effect modification. In addition, socioeconomic status is highly nuanced and complex construct. It is quite possible the use of private insurance status as a proxy measure for SES could result in misclassification, also compromising the ability to understand the potential for interaction.

Limited data on schools and classroom variables also meant there could be some unmeasured confounders we could not control for in our analyses. Depending on how much the classroom environment affects visual development, controlling for these variables could further attenuate the effect of visual impairment. Lastly, it should be noted the ReadAlyzer may have more limited reliability in subjects with worse vision impairment. The instrument is designed to measure normal eye movements and those with amblyopia often have different types of eye movements due to their condition.

Future Directions:

Currently, the definition of visual impairment on both the state and national level is determined by vision in the better-seeing eye. Consequently, children with amblyopia are considered to have normal vision when viewing with both eyes and are not eligible for any accommodations. Our study shows severe vision impairment even in just one eye has the potential to affect reading, especially among lower SES children. More research with larger sample sizes to investigate potential differences in the effect of vision impairment and oculomotor dysfunction on reading based on socioeconomic status is warranted. It is necessary to better understand the modifiers of relationship between vision and reading to inform the need for reading supports in schools and alleviate disparities in the functional impact experienced by children with amblyopia.

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Tables

Table 1. Characteristics of Study Population, Infant Aphakia Treatment Study (IATS) with Available Data on Silent Reading

	Near Normal VA N=22	Mild to Moderate VI N=31	Severe VI N=39
White, single race (N=78)	23.1%	33.3%	43.6%
All other races (N=14)	28.6%	35.7%	35.7%
Male (N=43)	25.6%	32.6%	41.9%
Female (N=49)	22.5%	34.7%	42.9%
Private Insurance (N=58)	31.0%	34.5%	34.5%
Public Insurance (N=34)	11.8%	32.4%	55.9%
Current Grade Level 3 (N=2)	0%	100%	0%
Current Grade Level 4 (N=41)	24.4%	36.6%	39.0%
Current Grade Level 5 (N=45)	24.4%	31.1%	44.4%
Current Grade Level 6 (N=2)	0%	0%	100%

Values are percentage for categorical variables

Table 2. Summary Statistics Comparing Reading Outcomes by Private Insurance Status among IATS Participants

	Private Insurance	Public Insurance	N, df	p-value
Reading Rate (words per minute)	171.0 (75.7)	149.5 (85.2)	N=92, df=90	0.21
Number of Regressive Saccades	32.1 (40.0)	45.7 (41.5)	N=92, df=90	0.12
Regressive/Fixation Ratio (%)	18.4 (11.6)	24.6 (13.1)	N=92, df=90	0.02

Values are mean (standard deviation)

Table 3. Summary Statistics Comparing 3rd Grade Silent Reading Outcomes at age 10 ½ Years by Visual Acuity Level among IATS Participants

Reading Outcome	Overall	Near Normal VA	Mild to Moderate VI	Severe VI	ANOVA n, df	p-value
Reading Rate (words per minute)	163.2 (79.2)	157.7 (64.8)	173.0 (78.9)	158.2 (88.6)	N=92, df=2	0.70
Number of Regressive Saccades	37.0 (40.7)	38.8 (40.3)	28.1 (35.9)	43.4 (44.5)	N=92, df=2	0.29
Regressive/Fixation Ratio (%)	20.7 (12.4)	21.7 (12.8)	18.1 (11.2)	22.2 (13.5)	N=92, df=2	0.36

Values are mean (standard deviation)

Table 4. Linear Associations between LogMAR VA in Treated Eye and Silent Reading Outcomes in IATS Participants (N=91)

	Crude β	p-value	Adjusted[1] β	p-value
Reading Rate (words per minute)	-12.87	0.37	-10.40	0.50
Number of Regressive Saccades	9.08	0.22	4.03	0.61
Regressive/Fixation Ratio (%)	2.80	0.21	0.82	0.73

[1]adjusted for sex, race (white vs. all others), SES (private vs. public insurance), and VA in the fellow eye (logMAR)

Table 5. Prevalence Odds Ratios for the Relationship Between Vision Impairment in the Treated Eye (Severe VI vs. Normal to Moderate VI) and Poor Reading Outcomes

Outcome	Visual Acuity	Number of Participants			Odds Ratio[1]
		Normal reading	Poor reading	Total	
Reading Rate <113 wpm	≤ 20/200	40	13	53	0.95 (0.35, 2.55)
	> 20/200	29	10	39	
# Regressive Saccades > 40	≤ 20/200	44	9	53	1.77 (0.63, 4.97)
	> 20/200	27	12	39	
Regressive/Fixation Ratio >25%	≤ 20/200	41	12	53	1.10 (0.41, 2.98)
	> 20/200	28	11	39	

[1]adjusted for sex, race (white vs. all others), SES (private vs. public insurance), and VA in the fellow eye (logMAR)

Table 6. Prevalence Odds Ratios for the Relationship Between Vision Impairment in the Treated Eye (Severe VI vs. Normal to Moderate VI) and Poor Reading Outcomes Stratified by SES

Outcome	Insurance Status	Visual Acuity	Number of Participants			Odds Ratio[1]
			Normal reading	Poor reading	Total	
Reading Rate <113 wpm	Private	≤ 20/200	28	10	38	0.48 (0.12, 2.02)
		> 20/200	17	3	20	
	Public	≤ 20/200	12	3	15	2.26 (0.45, 11.26)
		> 20/200	12	7	19	
# Regressive Saccades > 40	Private	≤ 20/200	32	6	38	0.93 (0.21, 4.22)
		> 20/200	17	3	20	
	Public	≤ 20/200	12	3	15	3.54 (0.72, 17.32)
		> 20/200	10	9	19	
Regressive/Fixation Ratio >25%	Private	≤ 20/200	29	9	28	0.35 (.07, 1.82)
		> 20/200	18	2	20	
	Public	≤ 20/200	12	3	15	3.61 (0.74, 17.66)
		> 20/200	10	9	19	

[1]adjusted for sex, race (white vs. all others), SES (private vs. public insurance), and VA in the fellow eye (logMAR)

Figures

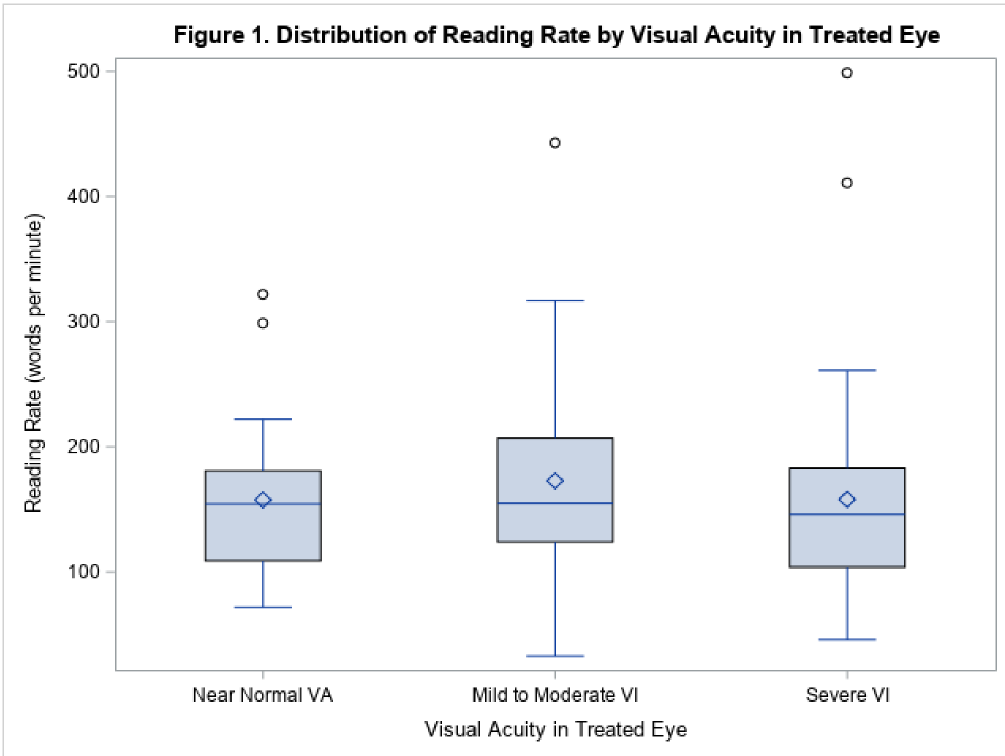
Figure 1. Distribution of Reading Rate by Visual Acuity in Treated Eye
Reading Rate (words per minute)
500
400
300
200
100
Near Normal VA
Mild to Moderate VI
Severe VI
Visual Acuity in Treated Eye

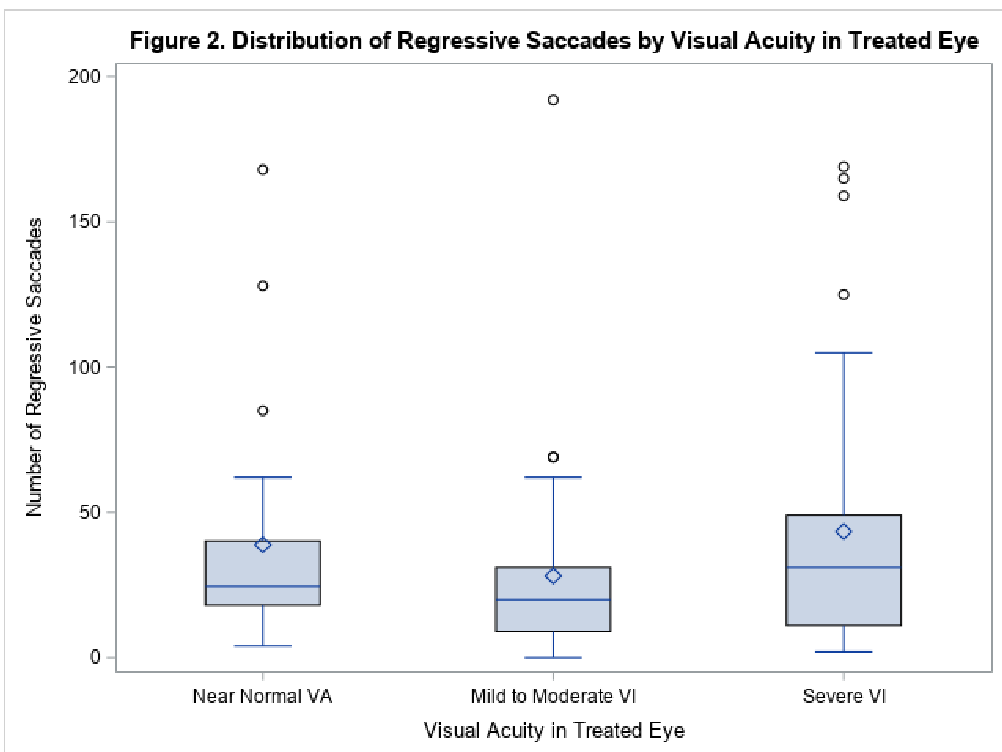
Figure 2. Distribution of Regressive Saccades by Visual Acuity in Treated Eye
Number of Regressive Saccades
200
150
100
50
0
Near Normal VA
Mild to Moderate VI
Severe VI
Visual Acuity in Treated Eye

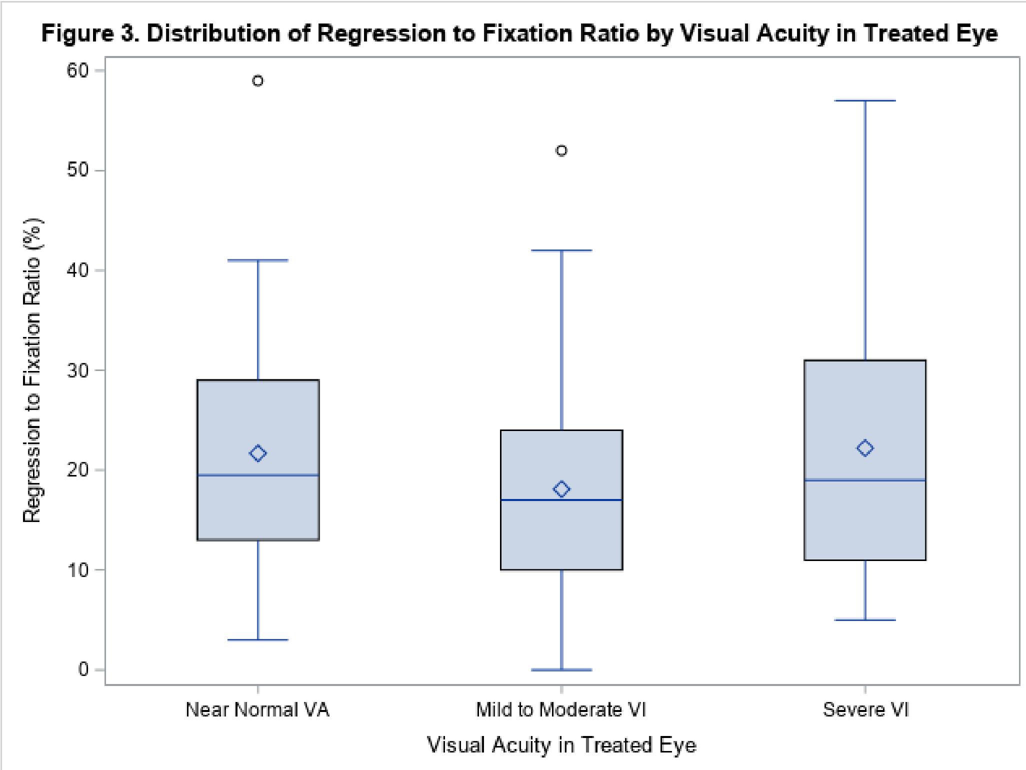
Figure 3. Distribution of Regression to Fixation Ratio by Visual Acuity in Treated Eye
60
50
40
30
20
10
0
Regression to Fixation Ratio (%)
Near Normal VA
Mild to Moderate VI
Severe VI
Visual Acuity in Treated Eye