In Plain Sight: Learning Outcomes of Providing Eyeglasses to Disadvantaged Students: An Evaluation of Vision for Baltimore

Revised Final Report to the Arnold Foundation

Amanda J. Neitzel, PhD
Rebecca Wolf, PhD
Xinxing Guo, MD, PhD
Ahmed F. Shakarchi, MBChB, MPH
Christine SySantos Levy, BA
Robert E. Slavin, PhD
Nancy A. Madden, PhD
Michael X. Repka, MD
David S. Friedman, MD, PhD
Megan E. Collins, MD, MPH

February 2021

Contents

In Plain Sight: Learning Outcomes of Providing Eyeglasses to Disadvantaged Students: An Evaluation of Vision for Baltimore....1
Background....1
Program Description....3
Research Design....3
Method....5
Sample....5
School sample....5
Student sample....6
Data....9
District data (Outcome Measures)....9
Vision data....10
Analytical Approach....10
Additional data points....12
Results....12
Overall achievement results....12
Differential achievement results: Student characteristics....14
Differential achievement results: Types and severity of refractive error....16
Attendance results....16
Best practices/lessons learned....16
Discussion....17
References....20
Appendix A: Cluster (School) Attrition....24
Appendix B: Baseline Equivalence....25
Student Characteristics....25
Pretest Equivalence....26
Appendix C: Refractive Error & Severity....28
Refractive error categories....28
Refractive error by severity....28
Astigmatism....29
Severity of Astigmatism....29

Visual impairment. 29
Appendix D: Regression Results 31
Overall achievement results. 31
Differential results: student characteristics. 32
Differential achievement results: types and severity of refractive errors. 36
Category of refractive error. 36
Severity of refractive error. 37
Astigmatism 40
Severity of astigmatism. 42
Visual impairment. 44
Results for attendance. 47

In Plain Sight: Learning Outcomes of Providing Eyeglasses to Disadvantaged Students: An Evaluation of Vision for Baltimore

Vision for Baltimore (V4B) is a city-wide partnership to provide school-based access to eye care for all students attending Baltimore City elementary and middle schools. The program is a partnership between the Baltimore City Public Schools System (BCPSS), the Baltimore City Health Department (BCHD), Johns Hopkins University (JHU), Vision To Learn (VTL), and Warby Parker. The program launched in the fall of 2016. Each year, the program has served approximately 45 elementary and middle schools in Baltimore City. All public schools in the city serving students in prekindergarten through eighth grade were served by program by spring 2019.

BCHD provided initial screening to all students in each school selected during a project year. Students who did not pass the vision screening provided by BCHD were offered an eye exam by optometrists in VTL's mobile vision clinic, which came directly to each school campus. If the eye exam indicated the student needed eyeglasses, they were able to pick the style and color of frame the same day in the mobile clinic with the help of an optician. Eyeglasses were manufactured by Warby Parker and delivered to students at their schools within two to four weeks. Since 2016, V4B has provided over 7000 pairs of eyeglasses to students with myopia (nearsightedness), hyperopia (farsightedness), and astigmatism.

In addition to providing students school-based vision care, there was a research component to the V4B project. Researchers at JHU conducted a rigorous cluster randomized trial to assess the impact of school-based vision care on reading and math achievement. This report presents findings from this research study, conducted by the Johns Hopkins University Center for Research and Reform in Education (CRRE) and the Wilmer Eye Institute, to determine the impact of providing eyeglasses to students who needed them on academic outcomes. The study focused on the impact of V4B's school-based vision services on student achievement as measured by summative and formative test scores in English language arts and mathematics. The study also explored differential impacts by student characteristics, as well as program impacts on student attendance and best practices/lessons learned.

Background

Reading is a vital skill, key to success in school, necessary for getting and maintaining employment, and essential for functioning in everyday life. Among historically underserved students, reading failure is far higher than it is among other students. For example, on the National Assessment of Educational Progress (National Center for Education Statistics, 2019), only 21% of fourth grade students qualifying for free- or reduced-price lunch scored at or above "proficient," in comparison to 51% of students who did not qualify for free lunch. Among African-Americans, 18% scored at

or above “proficient,” and among Hispanics, 23% did so, in comparison to 45% of Whites.

These differences are well known to education researchers and policy makers, and they have driven both research and policy for many years. Yet the performance of American students has not improved significantly since the 1990s (McFarland et al., 2017). Many attempts to solve this problem have focused on schools, including reform of instruction, yet “out of school” factors have a substantial impact on student learning (Clabaugh, 2008). These factors, such as blighted neighborhoods, reduced access to healthcare, and fewer opportunities for learning outside school, are often concentrated among students living in poverty (Berliner, 2009).

One non-school factor that is gaining traction as a part of the explanation for school failure is uncorrected vision problems. These correctable vision deficits are mainly related to refractive errors, including myopia, hyperopia, and astigmatism (Ruderman, 2016). Approximately 20-25% of school-age children need eyeglasses (Ferebee, 2004), yet disadvantaged and minority children are far less likely than middle class and white children to obtain and wear eyeglasses if they need them (Ganz et al., 2007; Heslin et al., 2006; Qiu et al., 2014; Ruderman, 2016; Zhang, Cotch, et al., 2012; Zhang, Elliott, et al., 2012). A New York City study, for example, found that 28% of disadvantaged middle school students needed eyeglasses , but only 7% had them (Bodack et al., 2010). A similar finding was seen in the Baltimore Reading and Eye Disease Study (Slavin et al., 2018).

One approach to solving the vision care access gap is school-based vision care. In these models, students who have failed a vision screening receive follow-up care and eyeglasses onsite at the school. Such approaches are growing in popularity and include programs such as ChildSight (part of the Helen Keller Foundation), VTL, and OneSight. These programs solve the leaking pipe of more traditional vision screening programs, where parents are informed that their child is in need of additional follow-up and asked to seek a provider in the community, an action that is frequently not taken (Clarke et al., 2008; Mark & Mark, 1999; Neville et al., 2015). Even once students are provided with vision services and appropriate vision care, they need to wear their eyeglasses regularly to benefit from them, and this is by no means assured (Alvi et al., 2015; Ethan et al., 2010; Kodjebacheva et al., 2014; Messer et al., 2012; Preslan & Novak, 1998). A comprehensive school-based model could include multiple strategies to not only provide access to care, but also involve the school staff to build a system to ensure regular, long-term use of eyeglasses.

Unmet vision needs, prevalent among high-poverty populations, are particularly important to address because of the association between vision and learning. While this link is accepted by many (Kodjebacheva et al., 2015), and there is some research to support a relationship between the use of appropriate eyeglasses and achievement (Dudovitz et al., 2016, 2020; Esteso et al., 2007; Hark et al., 2020; Pavithra et al.,

2014), there is a lack of rigorous evidence support the connection between provision of eyeglasses through a school-based program and improved achievement. One set of experimental studies comes from rural China, which did document positive effects of provision of eyeglasses to students who needed them on literacy (Hannum & Zhang, 2012) and math (Hannum & Zhang, 2012; Ma et al., 2014). Another randomized study from Florida showed positive impacts of provision of eyeglasses, but there were substantial implementation challenges that limit the claims that can be drawn from these results, as well as a student sample that included all students, not just those who failed a vision screening or were provided with eyeglasses. A clear demonstration of the academic impact of school-based interventions designed to ensure that disadvantaged children receive and wear eyeglasses has not been made in the United States. The research project implemented within the V4B project was designed to fill that gap using a rigorous experimental design.

Program Description

Starting in 2016, V4B began providing school-based vision care to elementary and middle school students in BCPSS. The first step of the program involved a vision screening conducted by BCHD of all students at each elementary and middle school selected for services that school year. These screenings identified students who may have vision deficits and require further follow-up. These identified students were invited to receive a follow-up eye exam from the program at their school. Students whose parents provided consent for participation in the program were scheduled to receive an eye exam in VTL's mobile eye clinic at the child's school. Eye exams were provided by licensed optometrists in the mobile clinic. Students who were determined to need prescription eyeglasses were able to choose the style and color of their frames at the time of the exam. Eyeglasses were donated by Warby Parker and dispensed to students at the school approximately two to four weeks after the eye exam.

Throughout the program, JHU provided implementation support services and technical assistance through school vision advocates (SVAs). SVAs assisted with the logistics of scheduling vision screenings and exams, and dispensing eyeglasses, as well as providing education and monitoring support to schools to ensure that students are wearing their eyeglasses. The V4B model is a comprehensive approach to school-based vision care, and as such provides more services and support, including the ongoing engagement with schools, than many other school-based vision programs.

Research Design

This cluster randomized, school-based study was conducted in public schools in Baltimore City that participated in the V4B program. Elementary and middle schools in Baltimore City were randomly assigned to one of three groups: receive the V4B services in the first year of the study (2016-2017, Cohort 1), receive the V4B services in the second year of the study (2017-2018, Cohort 2), or receive the V4B services in the third

year of the study (2018-2019, Cohort 3). Treatment was defined as students receiving eye exams and being prescribed eyeglasses by VTL. The research team was able to estimate impacts at the end of the first year for students in Cohort 1 (1-year impacts), at the end of the second year for students in Cohort 1 (2-year impacts), and for students in Cohort 2 (1-year impacts). While students in Cohort 3 were served by the program after posttests were collected, they were included in the study only as a delayed-treatment control group. Figure 1 below outlines the timeline of the program implementation and duration of treatment by the time the program impact on student achievement was measured for each cohort of schools.

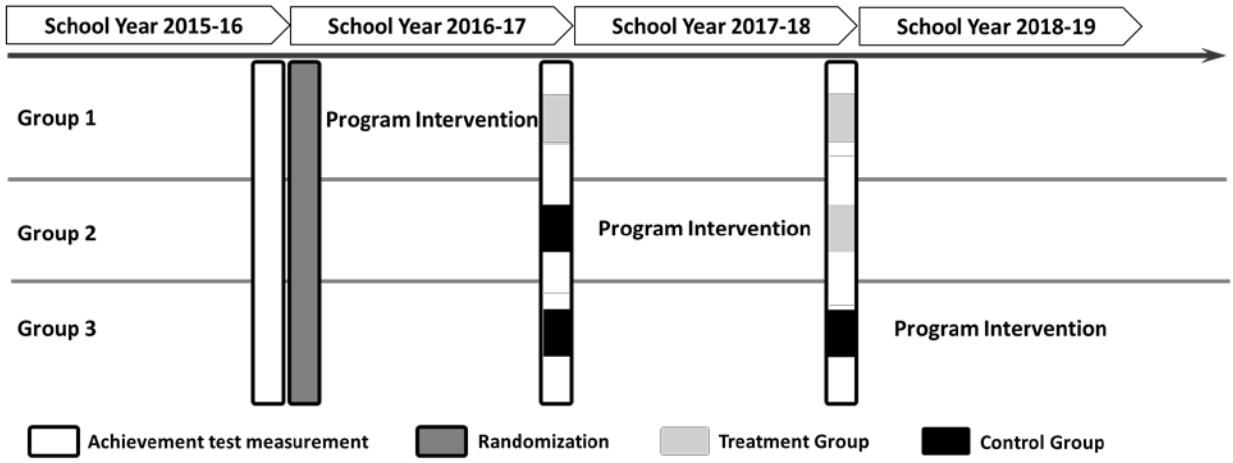


Figure 1. V4B research design.

This study was guided by the following research questions:

Primary Research Question

1. What were the effects of providing eyeglasses and school-based interventions to promote eyeglass usage on the reading and math achievement of students with refractive errors (myopia, hyperopia, and astigmatism) as measured by 2-year impacts on the PARCC?

Exploratory Research Questions

2. What were the effects of providing eyeglasses and school-based interventions to promote eyeglass usage on the reading and math achievement of students with refractive errors (myopia, hyperopia, and astigmatism) as measured by 1-year impacts on the PARCC as well as 1-year and 2-year impacts on the i-Ready?

3. How do the achievement effects of receiving eyeglasses vary for students by different characteristics (gender, grade, prior achievement, and special education participation)?

4. How did the effects of receiving eyeglasses on achievement vary for students with different types and severities of refractive error?

5. What were the effects of providing eyeglasses and school-based support for usage of eyeglasses on student attendance?

6. How can schools promote use of eyeglasses, develop strategies to reduce losses and breakage, and best provide replacement if eyeglasses are lost?

Method

Sample

School sample. There were 127 elementary and middle schools in Baltimore City Public Schools that were eligible to be included in the study, after excluding 24 schools that were alternative schools or served middle and high school students. Schools that had participated in an earlier pilot program, the Baltimore Reading and Eye Disease Study (BREDS), where all grades had already received school-based vision care, were also excluded. Schools were randomly assigned to one of three cohorts using the following blocking variables: charter school status, school type (e.g., elementary, middle, or K–8), whether the entire school had previously participated in BREDS, whether the school served a large percentage of low-income and Black students[1], and whether the school served a large percentage of Latino students.[2] Random assignment of schools was successful as shown in Table 1, in that schools in each cohort were similar in terms of students served.

Table 1. School-level mean percentages at randomization.

	Cohort 1 (%)	Cohort 2 (%)	Cohort 3 (%)
Black	82	82	84
White	9	9	10
Latino	6	6	5
Asian	1	1	1
Female	47	49	50
Low-income	89	89	86

[1] We first created a principal components score using school demographic characteristics and then divided schools into two groups using the median principal components score. This dichotomous variable then served as a blocking variable for school random assignment. The principal components score was most strongly correlated with percentage low-income, but also had a strong and positive correlation with percentage Black, as well as a strong and negative correlation with percentage White.

[2] Schools were divided into two groups based on whether they served more than 25% Latino students. This dichotomous variable served as a blocking variable for school random assignment.

English learner	5	4	3
Special education	14	15	14
	(N)	**(N)**	**(N)**
Elementary	15	16	16
Middle	3	3	3
Elementary & middle	24	23	24
Charter	9	8	8
School N	42	42	43

Attrition of schools was small, and mostly due to schools closing before they were served by the program[3]. The level of attrition was low for most of the outcomes examined (What Works Clearinghouse, 2020). Appendix A gives detailed information about the level of school attrition for each outcome included in the study. Even after the attrition of those schools, the sample remained comparable on observable characteristics at baseline (see Table 2).

Table 2. School-level mean percentages after attrition.

	Cohort 1 (%)	**Cohort 2 (%)**	**Cohort 3 (%)**
Black	84	82	84
White	8	10	9
Latino	5	6	5
Asian	1	1	1
Female	47	49	51
Low-income	89	89	87
English learner	5	4	3
Special education	14	15	14
	(N)	**(N)**	**(N)**
Elementary	15	16	14
Middle	3	3	2
Elementary & middle	23	22	22
Charter	8	8	7
School N	41	41	38

Student sample. The study sample included students who: (1) provided consent to be included in the research study, (2) received an eye exam and were prescribed eyeglasses by VTL, (3) had a baseline achievement test score, (4) had at

[3] Of the schools that left the study after randomization, one was not served because they had been served the year prior, one was unable to be scheduled for services, and five closed before they could be served.

least one achievement test score outcome, and (5) were in third through seventh grade during SY17-18. Student sample loss was due entirely to missing outcome or pretest data.

For students in all cohorts, we tracked achievement from prior to the implementation of V4B (spring 2016 or fall 2016 if students were not in the district in the spring of 2016) through the spring of 2017 and 2018. Students who had not yet been served by the program, but would be identified and served in the future, made up the comparison group. One key assumption of this process is that student vision does not substantially change from one year to the next. Therefore, we assume students in cohort 3 who were identified as needing eyeglasses in the 2018–19 school year would have almost all been identified as needing eyeglasses had they been in Cohorts 1 and 2 and provided an eye exam in an earlier school year. Similarly, students in Cohorts 1 and 2 identified as needing eyeglasses would almost all have been identified as needing eyeglasses had they been in Cohort 3 and not screened until the 2018–19 school year.

Characteristics of students included in the study were similar across the groups for both the primary research question (Table 3 for 2-year impacts in SY 17-18 with Cohort 1 vs Cohort 3) as well as for the exploratory research questions (Appendix B1-B2). In addition, fror each outcome measure, treatment and control students had acceptably similar pretest scores (What Works Clearinghouse, 2020), outlined in Table 4 for the primary research question (2-year impacts in SY 17-18 with Cohort 1 vs Cohort 3) as well as for other outcomes and timepoints in the exploratory research questions (Appendix B3). Because the program could have theoretically impacted student characteristics, such as special education status, we used the student characteristics from prior to program implementation, taken from either the spring of 2016 or fall of 2016 if students were not in the district in the spring of 2016. Comparisons across the student and school samples in terms of race/ethnicity were complicated by the fact that student race/ethnicity was determined as being mutually exclusive in the school-level demographic characteristics from the Maryland Report Card data, but in the student sample data from the school district, students were often classified as being of more than one race or ethnicity.

The sample was limited to students in grades 3-7 in SY17-18, along with the corresponding same-age control students[4]. This should have resulted in similar numbers of students from each grade participating; however, there were small differences in the proportions of students from each grade across the cohorts. This appears due to random chance.

[4] This approach was necessary to ensure the availability of both pretest and posttest data, as well as similar balance in ages across groups. Eighth grade students could not be included because the students in cohort 3 weren't identified until SY18-19, when those students would have been in ninth grade, attending schools not served by the program.

Table 3. Primary research question: Student-level percentages of the analytic sample at baseline for 2-year impacts in SY 17-18.

2-year impacts (SY 17-18: Cohort 1 vs Cohort 3)	Cohort 1 (%)	Cohort 3 (%)
Black	78	80
White	17	19
Latino	16	17
Asian	2	0
Female	52	57
English learner	9	10
Special education	18	18
1st grade	17	23
2nd grade	23	23
3rd grade	26	19
4th grade	21	19
5th grade	13	16
Student N	963	565

Table notes. 1. Student race/ethnicity was not mutually exclusive, and students may have classified as more than one race/ethnicity. Therefore, percentages by student race/ethnicity may sum to more than 100%. 2. The sample size of Cohort 3 is due mainly to school attrition in the final year, so that fewer students were screened.

Table 4. Primary research question: Student-level pretest equivalence of the analytic sample at baseline for 2-year impacts on PARCC in SY 17-18.

Pretest	Treatment Schools	Control Schools	Treatment Students	Control Students	Treatment Mean	Control Mean	Treatment SD	Control SD	Effect Size
				ELA					
PARCC	41	27	481	285	705.13	711.05	29.83	33.89	-0.19
i-Ready	33	32	228	140	462.64	461.45	56.03	49.59	+0.02
Pooled	41	37	709	425					-0.12
				Mathematics					
PARCC	41	27	481	286	710.31	714.74	29.00	31.78	-0.15
i-Ready	34	33	381	269	398.16	396.43	30.12	27.78	+0.06
Pooled	41	38	862	555					-0.05

Table note. Prior achievement for the PARCC analyses included students' PARCC scores in the same subject in spring 2016, or i-Ready beginning-of-the-year scores in fall 2016 when students were missing prior PARCC scores. A dummy variable was added to the model to indicate which pretest was used, as well as an interaction term between the dummy variable and students' beginning-of-the-year i-Ready score. Prior achievement for the i-Ready analyses included students' i-Ready beginning-of-the-year scores in fall 2016 in the same subject.

We used an intent-to-treat student sample, and students were included in the achievement sample if they had received eyeglasses through the V4B program and then transferred to another school within BCPSS. We could not track students who

transferred outside the district. Moreover, given the nature of the treatment (e.g., prescription of eyeglasses), students' treatment condition was determined by the timing and school where they had been prescribed eyeglasses.[5] Therefore, it is possible that students moved among schools in different cohorts over the course of the study, but were retained in the treatment condition determined by their VTL screening. We do not think it plausible, however, that students made school changes for the purpose of receiving V4B services.

Data

District data (Outcome Measures). To estimate the impact of receiving school-based vision services on student achievement and attendance, we collected individual student demographic, achievement, and attendance data from BCPSS for the 2015–16 through 2017–18 school years. The study examines the impact of V4B on the following measures:

- PARCC mathematics and English language arts tests administered to students in third through eighth grade. PARCC scale scores range from 650 to 850 for students within each grade level. The PARCC outcomes were our primary pre-specified outcomes.
- i-Ready end-of-year tests in mathematics and English language arts administered to students in Kindergarten through eighth grade. Student scores on i-Ready range from approximately 300 to 800, with students in lower grade levels expected to score lower than students in older grade levels. The i-Ready outcomes were additional achievement outcomes.
- Days present. Days present was determined only if students attended the schools in which they received vision services for at least 30 school days. The variable ranged from 30 to 180 school days.

To estimate program impacts on student attendance, we determined days present at schools where students received vision services through V4B. We hypothesized that student attendance may have been improved in schools where educators and school vision advocates were working to promote not only provision of, but also ongoing use of eyeglasses. As such, we did not track student attendance if students moved out of their vision school after receiving vision services. We also limited the sample to students who had attended their vision school for at least 30 school days in the school year.

[5] One implication is that this study includes "late student joiners" per the What Works Clearinghouse (2020) and therefore must show equivalence on pretest measures for each outcomes analysis.

Vision data. To identify students who were prescribed eyeglasses and to classify them based on their type and severity of refractive error, student vision data were also collected from VTL. Vision data included the following variables:

- Prescription for eyeglasses: As previously described, students with refractive error that would benefit from prescription were prescribed eyeglasses by VTL doctors.
- Type of refractive error: Refractive error type included myopia, hyperopia, and astigmatism.
- Severity of refractive error: Myopia and hyperopia were classified as mild, moderate, or severe; astigmatism was classified as low and high.

Appendix C includes more details about how the types and severities of refractive error were determined.

Analytical Approach

To compare student achievement in English language arts and mathematics for V4B and control students, we used hierarchical linear modeling, where students were nested within the schools where they received V4B services. The treatment was a schoolwide intervention, and students' treatment status was determined by the school where they received V4B services.[6]

For the student achievement analyses, we controlled for students' baseline achievement, as indicated by the pretest measure[7]. For each outcome measure, treatment and control students had acceptably similar pretest scores (What Works Clearinghouse, 2020), outlined in Appendix B3. For the attendance analyses, we controlled for student and school characteristics but did not control for baseline attendance, given student mobility within the district and the complications of students each having an attendance record at every school attended. Table 5 outlines the outcome and pretest measures for each analysis.

Table 5. Outcome and pretest measures by year

[6] Students may have attended schools other than their V4B school in the year prior to or after the school year when they received vision services. To the extent that this happened, the estimated standard errors may be biased due to dependence among the student observations. However, accounting for the clustering of students within their vision schools accounts for much of the dependence among student observations because the vast majority of students remained in their vision schools.

[7] Prior achievement for the PARCC analyses included students' PARCC scores in the same subject in spring 2016, or i-Ready beginning-of-the-year scores in fall 2016 when students were missing prior PARCC scores. A dummy variable was added to the model to indicate which pretest was used, as well as an interaction term between the dummy variable and students' beginning-of-the-year i-Ready score. Prior achievement for the i-Ready analyses included students' i-Ready beginning-of-the-year scores in fall 2016 in the same subject.

Results	Contrast	Outcome measure	Pretest measure
Primary Research Question			
2-year results	SY 17-18: Cohort 1 vs Cohort 3	PARCC spring 2018	PARCC spring 2016 if available, i-Ready fall 2016 if not available
Exploratory Research Questions			
1-year results	SY 16-17: Cohort 1 vs Cohorts 2 & 3	PARCC spring 2017	PARCC spring 2016 if available, i-Ready fall 2016 if not available
		i-Ready spring 2017	i-Ready fall 2016
		Days present in 2016–17	No pretest measure
	SY 17-18: Cohort 2 vs Cohort 3	PARCC spring 2018	PARCC spring 2016 if available, i-Ready fall 2016 if not available
		i-Ready spring 2018	i-Ready fall 2016
		Days present in 2017–18	No pretest measure
2-year results	SY 17-18: Cohort 1 vs Cohort 3	i-Ready spring 2018	i-Ready fall 2016
		Days present in 2017–18	No pretest measure

In addition to the pretest measures in the achievement analyses, the models also controlled for other student and school characteristics including:

- At the student level: Grade level.
- At the school level: Treatment condition (V4B or control) and blocking variables used in the school random assignment process: charter school status, school type (e.g., elementary, middle, or K–8), whether the school had previously participated in a school-based vision pilot study, whether the school served a large percentage of low-income and Black students, and whether the school served more than 25% Latino students.

We analyzed the 1-year impacts at the end of each year of the project, as well as the 2-year impacts at the end of the project. The 1-year impacts were pooled using a meta-analytic technique that was only reported for the main impact analyses, due to the low power of combining two estimates in this method.

We also examined whether there appeared to be differential effects of V4B for students based on demographic characteristics, prior achievement, and refractive errors types or severity. To do so, we added interaction terms between the V4B indicator and student-level covariates of interest. We then determined whether students with specific characteristics who received V4B services outperformed similar, comparison peers.

Additional data points

The fifth research question, describing lessons learned and best strategies for implementation, uses a variety of other methodologies (qualitative approaches, multiple baseline design, information gathered from key informants). The sample, data, and analytic approaches for these results are not described here, but are outlined in detail in other papers (Inns, 2018; Vongsachang et al., 2020).

Results

Overall achievement results. The outcomes for all students are summarized in Tables 6-7 and Figures 2-5. The primary outcome indicator is effect size, which represents the separation between the treatment and control groups in units of standard deviation for the outcome measures.

Primary research question. Results of the 2-year impacts on PARCC achievement are reported in Table 6. The 2-year impacts on PARCC ELA (ES = -0.04, Figure 2) and PARCC Mathematics (ES = 0.00, Figure 3) in SY 17-18 were not significant.

Table 6. Primary research question: Impacts on achievement for all students for 2-year impacts on PARCC in SY 17-18.

Subject	Outcome	Year	School N	Student N	Average score for comparison students	Average V4B difference (SE)	Effect Size	p Value
2-year results								
ELA	PARCC	SY 17-18	78	1134	698.83	-1.29 (1.75)	-0.04	0.46
Math			78	1417	724.19	0.13 (2.09)	0.00	0.95

Table note. 1. Effect sizes are experimental minus control means divided by the pooled standard deviation. 2. The models also controlled for student grade level, prior student achievement, and blocking variables used in random assignment (charter school status, school type, pilot study participation, school proportion of low-income and Black students, and whether the school served more than 25% Latino students). 3. The 1-year results from SY 16-17 and SY 17-18 were pooled using a fixed-effects meta-analysis model.

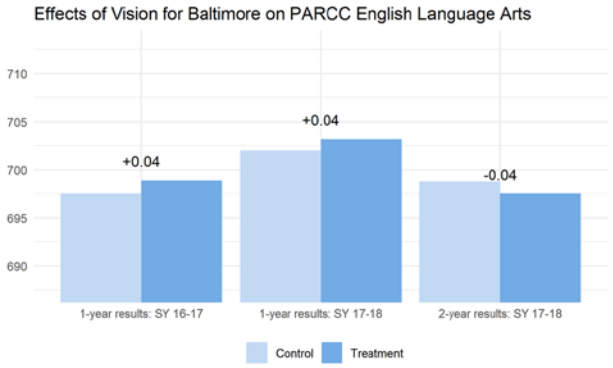


Figure 2.

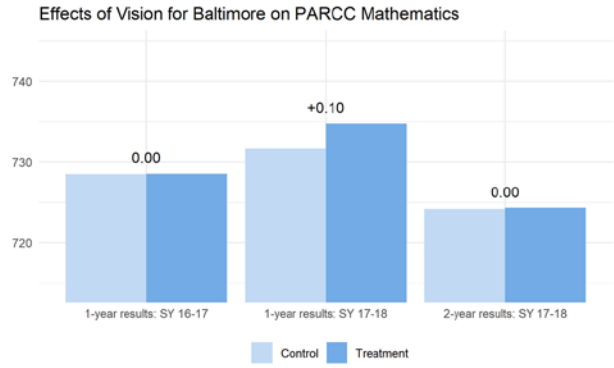


Figure 3.

Exploratory research questions. Results of the exploratory research questions on achievement are reported in Table 7. On the i-Ready ELA outcome (Figure 4), there was a positive impact of V4B for the 1-year results at the end of the 16-17 school year, with an effect size of +0.09 ($p < .05$). One-year results at the end of the 17-18 school year were similar (ES = +0.12, $p = .09$). The two-year results at the end of the 17-18 school year were similar in magnitude, but not statistically significant (ES = +0.08, n.s.). On the i-Ready Mathematics measure (Figure 5), outcomes were positive for students in the one-year sample at the end of SY 17-18 (ES = +0.09) and in the two-year sample at the end of SY 17-18 (ES = +0.08), but neither was statistically significant. This pattern was not observed in the one-year impacts at the end of SY 16-17 (ES = 0.00). The 1-year impacts on PARCC ELA (Figure 2) and PARCC Mathematics (Figure 3) were not significant in either SY 16-17 or SY 17-18.

Table 7. Exploratory research questions: Impacts on achievement for all students.

Subject	Outcome	Year	School N	Student N	Average score for comparison students	Average V4B difference (SE)	Effect Size	p Value
1-year results								
ELA	i-Ready	SY 16-17	107	1519	513.71	5.07 (2.11)	+0.09*	0.02
	PARCC		118	1773	697.53	1.39 (1.37)	+0.04	0.31
Math	i-Ready		106	1516	448.24	-0.09 (1.23)	0.00	0.94
	PARCC		119	1792	728.53	0.04 (1.21)	0.00	0.97
ELA	i-Ready	SY 17-18	65	754	532.27	7.85 (4.56)	+0.12	0.09
	PARCC		78	1016	701.99	1.23 (2.24)	+0.04	0.59
Math	i-Ready		66	1039	449.86	3.50 (1.87)	+0.09	0.07
	PARCC		79	1305	731.64	3.12 (1.91)	+0.10	0.11

ELA	i-Ready	Pooled					+0.10	0.20
	PARCC						+0.04	0.60
Math	i-Ready						+0.03	0.70
	PARCC						+0.04	0.60
2-year results								
ELA	i-Ready	SY 17-18	67	916	529.64	4.85 (4.01)	+0.08	0.23
Math			69	1197	449.51	2.94 (2.29)	+0.08	0.20

Table note. 1. Effect sizes are experimental minus control means divided by the pooled standard deviation. 2. The models also controlled for student grade level, prior student achievement, and blocking variables used in random assignment (charter school status, school type, pilot study participation, school proportion of low-income and Black students, and whether the school served more than 25% Latino students). 3. The 1-year results from SY 16-17 and SY 17-18 were pooled using a fixed-effects meta-analysis model.

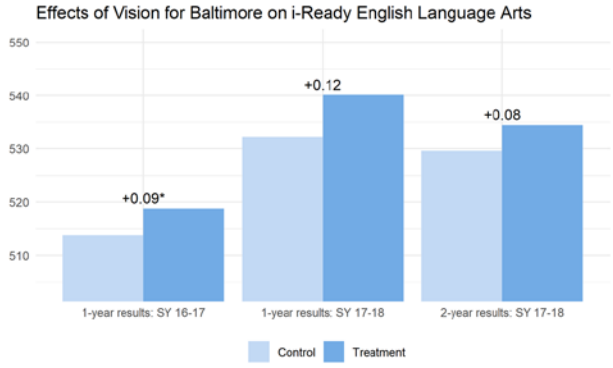


Figure 4.

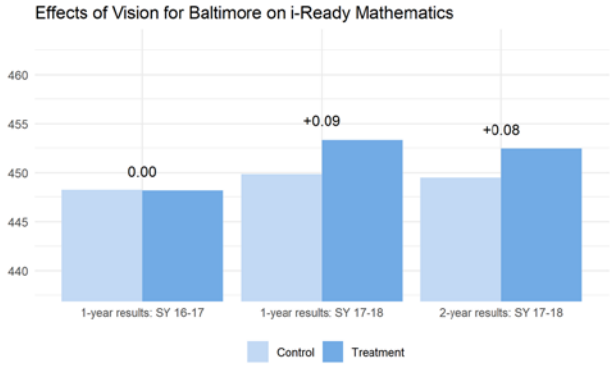


Figure 5.

Differential achievement results: Student characteristics. In addition to examining impacts for all students who received eyeglasses, we also explored whether impacts varied for different student subgroups, including by baseline achievement level, gender, grade level, and special education status. Differential effects were identified among students based on grade level and baseline achievement (Appendix D2). For students performing in the lowest 25% at baseline (low achievers), there was a significant positive impact of receiving eyeglasses on i-Ready ELA in the 1-year results in SY 16-17 (Figure 6; ES = +0.28, $p < .01$), much larger than the impact for students who were average and high achievers (ES = +0.03, n.s.). This pattern of stronger impacts for students performing in the lowest 25% was not observed in the 1-year results in SY 17-18 or in the 2-year results. Additionally, students in the elementary grades had impacts (ES = +0.03, $p < .01$) that were significantly different from those observed in the middle grades (ES = -0.21, n.s.) on the Math i-Ready test for the 1-year results in SY 16-17 (Figure 7). This pattern of differential results was not repeated in the 1-year results in SY 17-18 or the 2-year results. Finally, girls (ES = +0.11, n.s.) had significantly higher 2-year impacts than boys (ES = -0.12, n.s.) on the PARCC mathematics test (Figure 8).

Two additional findings are worth noting. The differential results for students receiving special education services, while mostly not significant, are meaningful. The effects of V4B on i-Ready ELA were large in both years for students participating in special education (1-year results SY 16-17: ES = +0.25, p < .01; 1-year results SY 17-18: ES = +0.24, n.s., 2-year results SY 17-18: ES = +0.23, n.s.), though this was only significant in SY 16-17 (Figure 9). In addition, girls had larger impacts than boys at the end of Year 1 on i-Ready ELA, however this was not significantly different (Figure 10; girls: ES = +0.15, p < .01, boys: ES = +0.01, n.s.).

Full results for all subgroups are reported in Appendix D2 and D3.

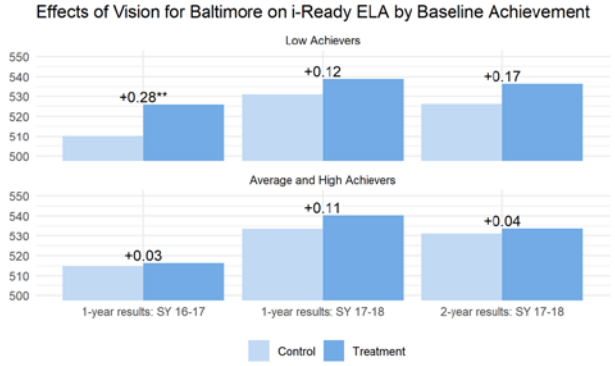


Figure 6.

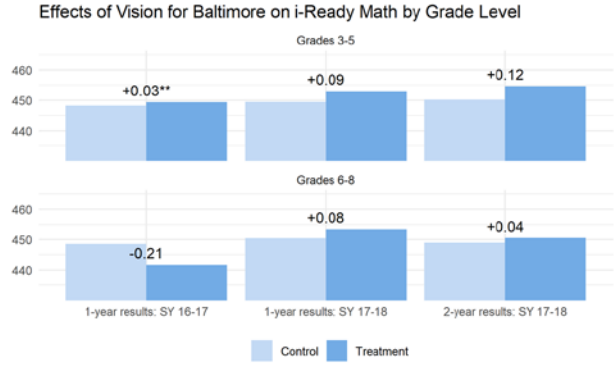


Figure 7.

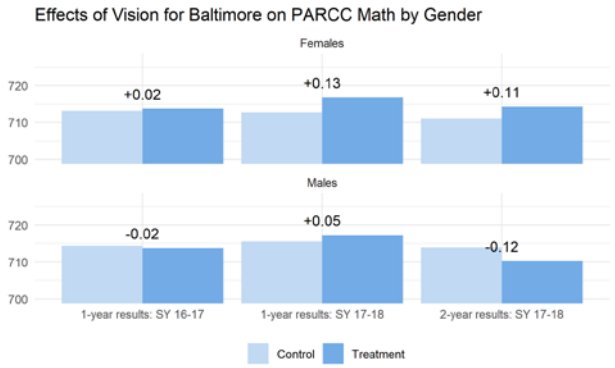


Figure 8.

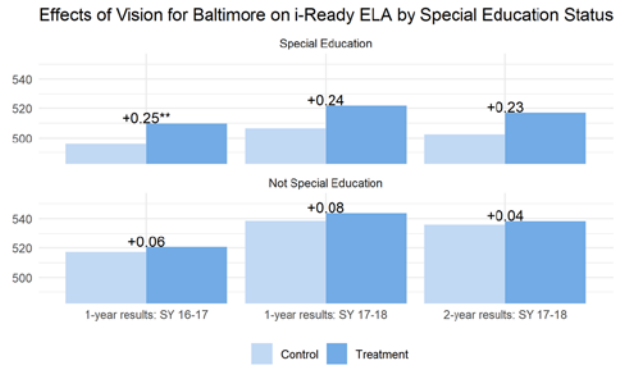


Figure 9.

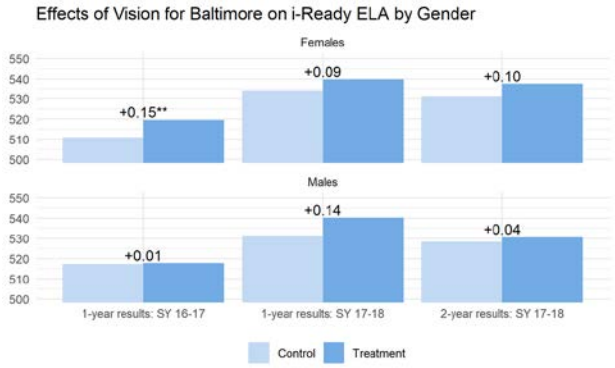


Figure 10.

Differential achievement results: Types and severity of refractive error. We explored whether impacts varied for groups with students with different types and severity of refractive error. No differential effects were identified for any of these groups, with the exception of students with astigmatism (Appendix D4-D13). This means that the positive impact of eyeglasses did not vary according to type of refractive error, severity of refractive error, or level of presenting visual impairment. For the single finding for students with astigmatism, the pattern was not observed for any other year or outcome, so this must be interpreted with caution, as this may be a spurious result.

Attendance results. We also estimated the impact of V4B on student attendance as measured by number of days present (Table 8). There were no significant effects on attendance in either the one-year results (SY 16-17 ES = -0.06, SY 17-18 ES = -0.01) or the two-year results (ES = -0.10).

Table 8. Impacts on attendance for all students

Year	School N	Student N	Average days present for comparison students	Average V4B difference	Effect Size	p Value
			1-year results			
SY 16-17	113	1582	166.92	-0.96 (1.05)	-0.06	.36
SY 17-18	78	1207	164.32	-0.13 (1.83)	-0.01	.94
			2-year results			
SY 17-18	77	1144	164.14	-2.20 (1.62)	-0.10	.18

Table note. 1. Effect sizes are experimental minus control means divided by the pooled standard deviation. 2. The models also controlled for student grade level and blocking variables used in random assignment (charter school status, school type, pilot study participation, school proportion of low-income and Black students, and whether the school served more than 25% Latino students).

Best practices/lessons learned. Based on our experiences implementing V4B over the three years of the project, we have identified several key factors that must be in place for successful implementation. These include relationship-building, parent engagement, systems for monitoring and replacing eyeglasses, and data sharing procedures. Each is explored more fully below.

Relationship-building. One of the key ingredients to the success of the V4B project has been the work of the school vision advocates (SVAs) in building strong relationships with our project partners and with the schools we have served. The SVAs worked closely with the personnel providing the screenings, exams, and eyeglasses dispensing, as well as the administration, faculty, staff, and students at the schools served by the program. Their interactions ranged from phone-call check-ins to presenting at staff meetings to classroom visits. The SVAs became trusted allies who were available to answer questions and troubleshoot problems. They also were able to

build awareness of and excitement about the program, and provide support to schools to overcome barriers to implementation. This relationship building took place at all levels of the school district, starting with students and staff at schools, and continuing all of the way up to developing relationships and ongoing engagement with district level leadership.

Parent engagement. Another lesson learned from this project was the importance of positive and ongoing engagement with parents. The program was most effective when parents were supporting the use and maintenance of eyeglasses. This required outreach to parents and addressing any questions or concerns they had about vision and eyeglasses. SVAs reached out to parents in many ways, such as inserts to classroom newsletters, holding parent breakfasts, providing education about vision, and being available to answer questions. This involvement of parents was an important factor in successful implementation.

Systems for maintenance. Another key lesson solidified in this project is the importance of ongoing efforts to ensure the regular use and replacement of eyeglasses (as needed). This means schools must develop systems to monitor eyeglasses use and replace eyeglasses as needed. The SVAs worked with schools to create a general framework for an eyeglasses maintenance system, which was then tailored to each school. For example, all schools developed monthly eyeglasses checks, the results of which were shared with the SVAs.

Data sharing procedures. The final lesson that was key to strong implementation of V4B was the need for clear procedures for efficient and timely sharing of data that maintained privacy and security of the student level data. Given the scale of this project, efficient methods of transferring and sharing information were needed, which met all partners' requirements for security and worked with their independent data systems. Program partners developed a Memorandum of Understanding to ensure a protocol and safety standards for sharing data among partners.

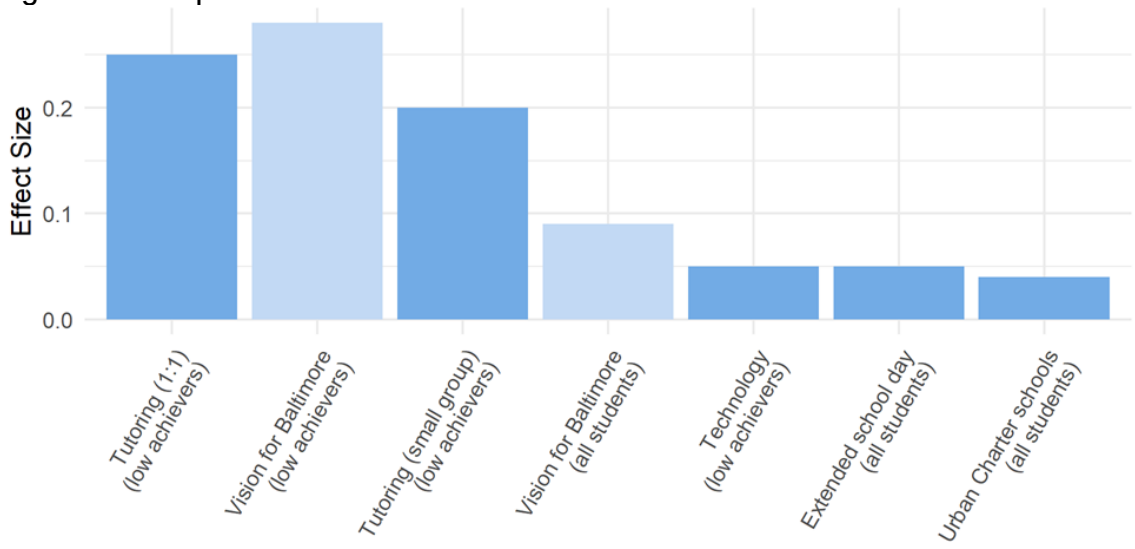
Discussion

In this study, we did not identify an impact of the V4B intervention on the primary outcome, the 2-year impact on PARCC achievement. However, there were promising findings in the exploratory questions. We found that students at schools randomized to receive school-based examination and eyeglasses achieved higher scores on the i-Ready standardized reading assessment when compared to control students at schools randomized to receive the school-based intervention after the study. Students in special education and those scoring in the lowest quartile at baseline showed the greatest benefits. There was no significant impact of the school-based eye exam and eyeglasses on i-Ready Mathematics or on PARCC standardized assessments.

The 1-year findings for i-Ready ELA (ES = +0.09) corroborate those of a previous, smaller study of reading effects of eyeglasses in Baltimore (ES = +0.16) (Slavin et al., 2018). Two studies in rural China (Hannum & Zhang, 2012; Ma et al., 2014) also found positive achievement effects of providing eyeglasses, but in both cases the outcome measures were standardized mathematics tests. These studies did not assess the impact of eyeglasses on reading performance. It is unclear why children in rural China had improved mathematics performance upon receiving eyeglasses when the children in our cohort did not show the same benefit. This observation may be related to differences in the tests between China and the US or difference between the rural population of China and the urban high-poverty community of Baltimore.

While significant effects were not seen on all measures, the positive outcomes on one district-administered reading test, the i-Ready, were significant for one cohort, with an effect size of +0.09. Importantly, outcomes for students in special education (ES = +0.25, +0.24, +0.23) and low achievers (ES = +0.28) were exceptional. As a point of comparison, Figure 8 shows mean effect sizes for various widely-used educational interventions for reading (CREDO, 2015; Figlio et al., 2018; Neitzel et al., in press). The modest overall effect size of +0.09 is larger than that for any other common intervention except tutoring. The effects for students in special education (ES = +0.25, +0.24, +0.23) and low achievers (ES = +0.28) are comparable to those of tutoring, the most effective educational intervention known. Based on the positive effect size measured on i-Ready ELA testing, this is estimated to be equivalent to one additional month of learning for all students, and three additional months of learning for students in special education and low achievers. These effects were found in a population-level intervention, including all students in third through eighth grade in Baltimore City.

Figure 8. Comparison of effect sizes of educational interventions.



Limitations. Because of the different outcomes on different measures, the results should be seen as promising rather than conclusive, especially given that this

study did not find an effect on the primary outcome, the 2-year impact on PARCC achievement. We conducted a research study which was done in the context of a real-world school-based program implementation encompassing over 30,000 students over a wide age range, and as such there may have been variations in techniques for screenings and exams that would not have occurred in a clinical trial setting. Also, the use of an intent-to-treat design meant that many of the students in the experimental groups may not have received their eyeglasses in time for their full impact to register on the spring tests. As a result, the effects may be an underestimate. Finally, we were not able to examine the difference in children below grade 3, as we did not have available data for a pre-test. Learning more about this age group would be important given the benchmark for reading proficiency is grade 3 and there is considerable interest in measures to improve reading in the early elementary school grades (K-2).

Conclusions. The findings of this study, if replicated, may provide schools with an important additional means of improving achievement on some types of outcomes for many students: providing eyeglasses to students who need them.

References

Alvi, R. A., Justason, L., Liotta, C., Martinez-Helfman, S., Dennis, K., Croker, S. P., Leiby, B. E., & Levin, A. V. (2015). The Eagles Eye Mobile: Assessing its ability to deliver eye care in a high-risk community. *Journal of Pediatric Ophthalmology & Strabismus*, *52*(2), 98–105.

Berliner, D. C. (2009). *Poverty and potential: Out-of-school factors and school success.* The Great Lakes Center for Education Research & Practice. https://eric.ed.gov/?id=ED507359

Bodack, M. I., Chung, I., & Krumholtz, I. (2010). An analysis of vision screening data from New York City Public Schools. *Optometry - Journal of the American Optometric Association*, *81*(9), 476–484. https://doi.org/10.1016/j.optm.2010.05.006

Clabaugh, G. K. (2008). Power failure: Must U.S. school reform miss the mark? *Education Digest*, *73*(5), 59–62.

Clarke, N., Shacks, J., Kerr, A. R. E., Bottrell, C. L., Poulsen, M. K., & Yin, L. (2008). Use of a noncycloplegic autorefractor to perform vision screening in preschools. *The Journal of School Nursing*, *24*(3), 158–163.

CREDO. (2015). *Urban charter school study report on 41 regions*. Center for Research on Education Outcomes. https://urbancharters.stanford.edu/download/Urban%20Charter%20School%20Study%20Report%20on%2041%20Regions.pdf

Dudovitz, R. N., Izadpanah, N., Chung, P. J., & Slusser, W. (2016). Parent, teacher, and student perspectives on how corrective lenses improve child wellbeing and school function. *Maternal and Child Health Journal*, *20*(5), 974–983. https://doi.org/10.1007/s10995-015-1882-z

Dudovitz, R. N., Sim, M. S., Elashoff, D., Klarin, J., Slusser, W., & Chung, P. J. (2020). Receipt of corrective lenses and academic performance of low-income students. *Academic Pediatrics*, S1876285920300024. https://doi.org/10.1016/j.acap.2020.01.001

Esteso, P., Castanon, A., Toledo, S., Rito, M. A. P., Ervin, A., Wojciechowski, R., & Congdon, N. G. (2007). Correction of moderate myopia Is associated with improvement in self-reported visual functioning among Mexican school-aged children. *Investigative Ophthalmology & Visual Science*, *48*(11), 4949–4954. https://doi.org/10.1167/iovs.07-0052

Ethan, D., Basch, C. E., Platt, R., Bogen, E., & Zybert, P. (2010). Implementing and evaluating a school-based program to improve childhood vision. *Journal of School Health*, *80*(7), 340–345.

Ferebee, A. (2004). *Childhood vision: Public challenges and opportunities. A policy brief*. Center for Health and Health Care in Schools, School of Public Health, George Washington University Medical Center.

Figlio, D., Holden, K. L., & Ozek, U. (2018). Do students benefit from longer school days? Regression discontinuity evidence from Florida's additional hour of literacy instruction. *Economics of Education Review*, *67*, 171–183. https://doi.org/10.1016/j.econedurev.2018.06.003

Ganz, M., Xuan, Z., & Hunter, D. G. (2007). Patterns of eye care use and expenditures among children with diagnosed eye conditions. *Journal of American Association for Pediatric Ophthalmology and Strabismus*, *11*(5), 480–487.

Hannum, E., & Zhang, Y. (2012). Poverty and proximate barriers to learning: Vision deficiencies, vision correction and educational outcomes in rural northwest China. *World Development*, *40*(9), 1921–1931.

Hark, L. A., Thau, A., Nutaitis, A., Mayro, E. L., Zhan, T., Dabbish, N., Tran, J., Siam, L., Pond, M., Rice, A. R., & Levin, A. V. (2020). Impact of eyeglasses on academic performance in primary school children. *Canadian Journal of Ophthalmology*, *55*(1), 52–57. https://doi.org/10.1016/j.jcjo.2019.07.011

Heslin, K. C., Casey, R., Shaheen, M. A., Cardenas, F., & Baker, R. S. (2006). Racial and ethnic differences in unmet need for vision care among children with special health care needs. *Archives of Ophthalmology*, *124*(6), 895–902.

Inns, A. J. (2018). *Implementation of school-based vision care in an urban district* [Doctoral Dissertation, Johns Hopkins University]. JScholarship. http://jhir.library.jhu.edu/handle/1774.2/60056

Kodjebacheva, G., Maliski, S., & Coleman, A. L. (2015). Use of eyeglasses among children in elementary school: Perceptions, behaviors, and interventions discussed by parents, school nurses, and teachers during focus groups. *American Journal of Health Promotion*, *29*(5), 324–331.

Kodjebacheva, G., Maliski, S., Yu, F., Oelrich, F., & Coleman, A. L. (2014). Decreasing uncorrected refractive error in the classroom through a multifactorial pilot intervention. *The Journal of School Nursing*, *30*(1), 24–30.

Ma, X., Zhou, Z., Yi, H., Pang, X., Shi, Y., Chen, Q., Meltzer, M. E., le Cessie, S., He, M., Rozelle, S., Liu, Y., & Congdon, N. (2014). Effect of providing free glasses on children's educational outcomes in China: Cluster randomized controlled trial. *BMJ*, *349*(sep23 7), g5740–g5740.

Mark, H., & Mark, T. (1999). Parental reasons for non-response following a referral in school vision screening. *Journal of School Health*, *69*(1), 35–38.

McFarland, J., Hussar, B., de Brey, C., Snyder, T., Wang, X., Wilkinson-Flicker, S., Gebrekristos, S., Zhang, J., Rathbun, A., Barmer, A., Mann, F. B., & Hinz, S. (2017). *The Condition of Education 2017* (NCES 2017-144). National Center for Education Statistics.

Messer, D. H., Mitchell, G. L., Twelker, J. D., Crescioni, M., Group, C. S., & others. (2012). Spectacle wear in children given spectacles through a school-based program. *Optometry and Vision Science: Official Publication of the American Academy of Optometry*, *89*(1), 19–26.

National Center for Education Statistics. (2019). *National Assessment of Educational Progress (NAEP), 2019 Reading Assessment*. U.S. Department of Education, Institute of Education Sciences, National Center for Education Statistics. https://www.nationsreportcard.gov/ndecore/xplore/NDE

Neitzel, A., Lake, C., Pellegrini, M., & Slavin, R. E. (in press). A synthesis of quantitative research on programs for struggling readers in elementary schools. *Reading Research Quarterly.*

Neville, K., Radii, E., & Velmer, G. (2015). Improving parental adherence to a failed vision screening referral in the United States. *British Journal of School Nursing*, *10*(3), 135–143.

Pavithra, M., Hamsa, L., & Madhukumar, S. (2014). Factors associated with spectacle-wear compliance among school children of 7-15 years in South India. *International Journal of Medicine and Public Health*, *4*(2), 146.

Preslan, M. W., & Novak, X. A. (1998). Baltimore Vision Screening Project. *Ophthalmology*, *105*(1), 150–153.

Qiu, M., Wang, S. Y., Singh, K., & Lin, S. C. (2014). Racial disparities in uncorrected and undercorrected refractive error in the United States. *Investigative Ophthalmology & Visual Science*, *55*(10), 6996–7005.

Ruderman, M. (2016). *Children's vision and eye health: A snapshot of current national issues* (1st ed.). National Center for Children's Vision and Eye Health at Prevent Blindness.

Slavin, R. E., Collins, M. E., Repka, M. X., Friedman, D. S., Mudie, L. I., Owoeye, J. O., & Madden, N. A. (2018). In plain sight: Reading outcomes of providing eyeglasses to disadvantaged children. *Journal of Education for Students Placed at Risk (JESPAR)*, *23*(3), 250–258. https://doi.org/10.1080/10824669.2018.1477602

Vongsachang, H., Friedman, D. S., Inns, A., Kretz, A. M., Mukherjee, M. R., Callan, J., Wahl, M., Repka, M. X., & Collins, M. E. (2020). Parent and teacher perspectives on factors decreasing participation in school-based vision programs. *Ophthalmic Epidemiology*, *27*(3), 226–236. https://doi.org/10.1080/09286586.2020.1730910

What Works Clearinghouse. (2020). *Standards Handbook (Version 4.1)*. Institute of Education Sciences, US Department of Education.

Zhang, X., Cotch, M. F., Ryskulova, A., Primo, S. A., Nair, P., Chou, C.-F., Geiss, L. S., Barker, L. E., Elliott, A. F., Crews, J. E., & Saaddine, J. B. (2012). Vision health disparities in the United States by race/ethnicity, education, and economic status: Findings from two nationally representative surveys. *American Journal of Ophthalmology*, *154*(6, Supplement), S53-S62.e1.

Zhang, X., Elliott, M. N., Saaddine, J. B., Berry, J. G., Cuccaro, P., Tortolero, S., Franklin, F., Barker, L. E., & Schuster, M. A. (2012). Unmet eye care needs among U.S. 5th-grade students. *American Journal of Preventive Medicine*, *43*(1), 55–58.

Appendix A: Cluster (School) Attrition

Year	Subject	Outcome	Treatment Schools	Control Schools	Schools Randomized to Treatment	Schools Randomized to Control	Attrited Treatment Schools	Attrited Control Schools	Overall Custer Attrition Rate	Differential Cluster Attrition Rate	Low Cluster Attrition?
1-year results											
SY 16-17	ELA	i-Ready	34	73	42	85	8	12	15.7	4.9	Yes
		PARCC	41	77	42	85	1	8	7.1	7	Yes
	Math	i-Ready	34	72	42	85	8	13	16.5	3.8	Yes
		PARCC	41	78	42	85	1	7	6.3	5.9	Yes
SY 17-18	ELA	i-Ready	33	32	42	43	9	11	23.5	4.2	Yes
		PARCC	41	37	42	43	1	6	8.2	11.6	No
	Math	i-Ready	33	33	42	43	9	10	22.4	1.8	Yes
		PARCC	41	38	42	43	1	5	7.1	9.2	Yes
2-year results											
SY 17-18	ELA	i-Ready	35	32	42	43	7	11	21.2	8.9	Yes
		PARCC	41	37	42	43	1	6	8.2	11.6	No
	Math	i-Ready	36	33	42	43	6	10	18.8	9	Yes
		PARCC	41	38	42	43	1	5	7.1	9.2	Yes

Appendix B: Baseline Equivalence

Student Characteristics.

B1. Exploratory research questions: Student-level percentages of the analytic sample at baseline for 1-year impacts in SY 16-17.

1-year impacts (SY 16-17: Cohort 1 vs Cohort 2 & Cohort 3)	Cohort 1 (%)	Cohort 2 & Cohort 3 (%)
Black	78	78
White	16	20
Latino	15	18
Asian	2	1
Female	53	58
English learner	8	8
Special education	18	17
2nd grade	27	28
3rd grade	31	29
4th grade	26	23
5th grade	16	20
Student N	799	1031

Table notes. 1. Student race/ethnicity was not mutually exclusive, and students may have classified as more than one race/ethnicity. Therefore, percentages by student race/ethnicity may sum to more than 100%.

B2. Exploratory research questions: Student-level percentages of the analytic sample at baseline for 1-year impacts in SY 17-18.

1-year impacts (SY 17-18: Cohort 2 vs Cohort 3)	Cohort 2 (%)	Cohort 3 (%)
Black	76	80
White	21	19
Latino	18	17
Asian	1	0
Female	56	57
English learner	8	10
Special education	17	18
1st grade	22	23

1-year impacts (SY 17-18: Cohort 2 vs Cohort 3)	Cohort 2 (%)	Cohort 3 (%)
2nd grade	21	23
3rd grade	25	19
4th grade	17	19
5th grade	15	16
Student N	775	565

Table notes. 1. Student race/ethnicity was not mutually exclusive, and students may have classified as more than one race/ethnicity. Therefore, percentages by student race/ethnicity may sum to more than 100%. 2. The sample size of Cohort 3 is due mainly to school attrition in the final year, so that fewer students were screened.

Pretest Equivalence.

B3. All research questions: Student-level pretest equivalence of the analytic sample.

Year	Subject	Outcome	Pretest	Treatment Schools	Control Schools	Treatment Students	Control Students	Treatment Mean	Control Mean	Treatment SD	Control SD	Effect Size
1-year results												
SY 16-17	ELA	i-Ready	i-Ready	34	73	695	824	491.13	494.83	56.51	59.53	-0.06
		PARCC	PARCC	41	67	533	696	705.4	711.18	30.35	32.52	-0.18
		PARCC	i-Ready	33	64	248	296	466.73	465.01	55.74	53.35	+0.03
	Math	i-Ready	i-Ready	34	72	689	827	426.77	429.34	32.82	33.95	-0.08
		PARCC	PARCC	41	68	533	693	710.39	714.8	29.35	31.94	-0.14
		PARCC	i-Ready	33	65	255	311	411.28	409.06	28.67	26.95	+0.08
SY 17-18	ELA	i-Ready	i-Ready	33	32	422	332	499.91	490.56	59.06	59.15	+0.16
		PARCC	PARCC	41	27	413	285	711.19	711.05	31.51	33.89	0.00
		PARCC	i-Ready	33	32	178	140	462.22	461.45	57.28	49.59	+0.01
	Math	i-Ready	i-Ready	33	33	579	460	418.32	416.5	36.98	38.28	+0.05
		PARCC	PARCC	41	27	407	286	714.49	714.74	31.96	31.78	-0.01
		PARCC	i-Ready	36	33	343	269	396.86	396.43	28.09	27.78	+0.02

				2-year results								
SY 17-18	ELA	i-Ready	i-Ready	35	32	584	332	490.34	490.56	56.64	59.15	0.00
		PARCC	PARCC	41	27	481	285	705.13	711.05	29.83	33.89	-0.19
		PARCC	i-Ready	33	32	228	140	462.64	461.45	56.03	49.59	+0.02
	Math	i-Ready	i-Ready	36	33	737	460	418.07	416.5	35.97	38.28	+0.04
		PARCC	PARCC	41	27	481	286	710.31	714.74	29	31.78	-0.15
		PARCC	i-Ready	34	33	381	269	398.16	396.43	30.12	27.78	+0.06

Table note. Prior achievement for the PARCC analyses included students' PARCC scores in the same subject in spring 2016, or i-Ready beginning-of-the-year scores in fall 2016 when students were missing prior PARCC scores. A dummy variable was added to the model to indicate which pretest was used, as well as an interaction term between the dummy variable and students' beginning-of-the-year i-Ready score. Prior achievement for the i-Ready analyses included students' i-Ready beginning-of-the-year scores in fall 2016 in the same subject.

Appendix C: Refractive Error & Severity

Refractive error categories.

Refractive error was categorized according to the following cutoffs:

- Hyperopia: Spherical Equivalent (SE) >= 0.5D in the better-seeing eye
- Myopia: SE <= -0.5D in the better-seeing eye
- Emmetropia: SE > -0.5D and SE < 0.5D in the better-seeing eyes

The better-seeing eye was defined as the eye with the better presenting visual acuity during VTL eye exam; if acuity was equivalent between the two eyes, the right eye was arbitrarily chosen as the better-seeing eye. If acuity was missing from the VTL eye exam, the better-seeing eye was determined as the eye with the better presenting visual acuity during screening.

C1.

Refractive Error (%)	Overall	Cohort 1	Cohort 2	Cohort 3
Emmetropia	568 (24.7)	249 (25.8)	217 (28.0)	102 (18.1)
Hyperopia	301 (13.1)	140 (14.5)	100 (12.9)	61 (10.8)
Myopia	1435 (62.3)	575 (59.6)	458 (59.1)	402 (71.2)

Refractive error by severity.

The severity of refractive error was categorized according to the following cutoffs:

- Myopia
  - Mild: SE -0.5 to -2.99 Diopters (D),
  - Moderate & Severe: SE ≤-3.00 D based on the better-seeing eye final prescription refraction.
- Hyperopia
  - Mild: SE +0.50 to +1.99 D
  - Moderate & Severe ≥ +2.00 D based on the better-seeing eye final prescription refraction.

C2.

Severity of Refractive Error (%)	Overall	Cohort 1	Cohort 2	Cohort 3
Emmetropia	568 (24.7)	249 (25.8)	217 (28.0)	102 (18.1)
Hyperopia: Mild	244 (10.6)	114 (11.8)	82 (10.6)	48 (8.5)
Hyperopia: Moderate & Severe	57 (2.5)	26 (2.7)	18 (2.3)	13 (2.3)

Myopia: Mild	1216 (52.8)	497 (51.6)	384 (49.5)	335 (59.3)
Myopia: Moderate & Severe	219 (9.5)	78 (8.1)	74 (9.5)	67 (11.9)

Astigmatism.

Astigmatism is defined as final prescription refraction cylindrical power ≥ 1 DC in the better-seeing eye.

C3.

Astigmatism (%)	**Overall**	**Cohort 1**	**Cohort 2**	**Cohort 3**
No	1390 (60.3)	556 (57.7)	493 (63.6)	341 (60.4)
Yes	914 (39.7)	408 (42.3)	282 (36.4)	224 (39.6)

Severity of Astigmatism.

Severity of astigmatism is determined based on the final refraction prescription cylindrical power in the better-seeing eye, using the following cutoffs:

- No astigmatism: <1.00 DC
- Low astigmatism: 1.00 – 2.75 DC
- High astigmatism: ≥ 3.00 DC,

where DC = diopter of cylinder

C4.

Severity of Astigmatism (%)	**Overall**	**Cohort 1**	**Cohort 2**	**Cohort 3**
No Astigmatism	1390 (60.3)	556 (57.7)	493 (63.6)	341 (60.4)
Low Astigmatism	799 (34.7)	355 (36.8)	244 (31.5)	200 (35.4)
High Astigmatism	115 (5.0)	53 (5.5)	38 (4.9)	24 (4.2)

Visual impairment.

Visual impairment category definitions were based on the better-seeing eye using the following cutoffs:

- No impairment: presenting visual acuity (VA) of 0.3 logMAR (Snellen Equivalent 20/40) or better;
- Mild impairment: presenting VA worse than 0.3 logMAR (20/40) and better than 0.48 logMAR (20/60);

- Moderate impairment: presenting VA worse than 0.48 logMAR (20/60) and better than 1.0 logMAR (20/200);
- Severe impairment & blindness: presenting VA worse than 1.0 logMAR (20/200).

C5.

Impairment (%)	Overall	Cohort 1	Cohort 2	Cohort 3
No Impairment	1483 (64.4)	653 (67.7)	487 (62.8)	343 (60.7)
Mild Impairment	332 (14.4)	139 (14.4)	108 (13.9)	85 (15.0)
Moderate Impairment	407 (17.7)	152 (15.8)	137 (17.7)	118 (20.9)
Severe Impairment & Blindness	82 (3.6)	20 (2.1)	43 (5.5)	19 (3.4)

Appendix D: Regression Results

Overall achievement results.

D1.

Subject	Outcome	Year	School N	Student N	Average score for comparison students	Average V4B difference	Effect Size	p Value
1-year results								
ELA	i-Ready	SY 16-17	107	1519	513.71	5.07 (2.11)	+0.09*	0.02
	PARCC		118	1773	697.53	1.39 (1.37)	+0.04	0.31
Math	i-Ready		106	1516	448.24	-0.09 (1.23)	0.00	0.94
	PARCC		119	1792	728.53	0.04 (1.21)	0.00	0.97
ELA	i-Ready	SY 17-18	65	754	532.27	7.85 (4.56)	+0.12	0.09
	PARCC		78	1016	701.99	1.23 (2.24)	+0.04	0.59
Math	i-Ready		66	1039	449.86	3.50 (1.87)	+0.09	0.07
	PARCC		79	1305	731.64	3.12 (1.91)	+0.10	0.11
ELA	i-Ready	Pooled					+0.10	0.20
	PARCC						+0.04	0.60
Math	i-Ready						+0.03	0.70
	PARCC						+0.04	0.60
2-year results								
ELA	i-Ready	SY 17-18	67	916	529.64	4.85 (4.01)	+0.08	0.23

Math	PARCC	78	1134	698.83	-1.29 (1.75)	-0.04	0.46
	i-Ready	69	1197	449.51	2.94 (2.29)	+0.08	0.20
	PARCC	79	1417	724.19	0.13 (2.09)	0.00	0.95

Table note: 1. The models also controlled for student grade level, prior achievement, and blocking variables used in random assignment (charter school status, school type, pilot study participation, school proportion of low-income and Black students, and whether the school served more than 25% Latino students), with no astigmatism as the reference group.

Differential results: student characteristics.

D2. Interaction terms.

Subject	**Test**	**Coefficient**	**1-Year results**				**2-Year results**	
			SY 16-17		SY 17-18		SY 17-18	
			Impact (SE)	p Value	Impact (SE)	p Value	Impact (SE)	p Value
ELA	i-Ready	treat:grade_level	6.73 (4.29)	.99	3.52 (5.38)	.99	5.42 (5.17)	.99
		treat:female	8.37 (3.10)	.80	-3.56 (5.07)	.99	4.08 (5.11)	.99
		treat:iep	10.55 (4.40)	.99	10.24 (7.05)	.99	12.09 (7.04)	.99
		treat:low_achiever	14.04 (3.79)	<.01	1.27 (6.31)	.99	7.83 (6.18)	.99
Math		treat:grade_level	8.02 (2.48)	<.01	0.57 (2.50)	.99	2.82 (2.46)	.99
		treat:female	2.55 (1.76)	.99	-3.67 (2.43)	.99	-1.48 (2.47)	.99
		treat:iep	-0.85 (2.47)	.99	-1.69 (3.41)	.99	2.32 (3.44)	.99

		treat:low_achiever	3.04 (2.15)	.99	-1.02 (3.00)	.99	1.93 (3.01)	.99
ELA	PARCC	treat:grade_level	0.89 (2.61)	.99	-0.17 (2.96)	.99	2.68 (2.66)	.99
		treat:female	1.68 (1.97)	.99	-0.17 (2.85)	.99	1.84 (2.70)	.99
		treat:iep	1.31 (2.68)	.99	-3.14 (3.84)	.99	-0.08 (3.59)	.99
		treat:low_achiever	1.99 (2.28)	.99	-1.13 (3.26)	.99	2.67 (3.06)	.99
Math		treat:grade_level	0.61 (2.55)	.99	4.56 (2.47)	.99	1.89 (2.33)	.99
		treat:female	1.11 (1.93)	.99	2.41 (2.43)	.99	6.97 (2.36)	<.01
		treat:iep	0.65 (2.65)	.99	1.92 (3.31)	.99	6.16 (3.21)	.99
		treat:low_achiever	0.04 (2.27)	.99	4.38 (2.90)	.99	1.29 (2.79)	.99

D3. Adjusted mean impacts and effect sizes by category and subgroup.

				1-Year results				2-Year results	
				SY1617		**SY1718**		**SY1718**	
Subject	**Test**	**Category**	**Subgroup**	**Impact**	**Effect Size**	**Impact**	**Effect Size**	**Impact**	**Effect Size**
ELA	i-Ready	Grade Level	Middle Grades	-0.59	-0.01	4.88	+0.08	1.33	+0.02
			Elementary Grades	6.14	+0.11	8.40	+0.13	6.75	+0.11
		Gender	Females	8.73	+0.15**	5.44	+0.09	6.39	+0.10
			Males	0.36	+0.01	9.00	+0.14	2.31	+0.04

Subject	Test	Category	Subgroup	1-Year results				2-Year results	
				SY1617		SY1718		SY1718	
				Impact	Effect Size	Impact	Effect Size	Impact	Effect Size
		Special Education Status	Special Education	13.87	+0.25**	15.41	+0.24	14.50	+0.23
			Not Special Education	3.32	+0.06	5.17	+0.08	2.41	+0.04
		Baseline Achievement	Low 25% at Baseline	15.54	+0.28**	7.88	+0.12	10.27	+0.17
			Top 75% at Baseline	1.50	+0.03	6.61	+0.11	2.44	+0.04
	PARCC	Grade Level	Middle Grades	0.97	+0.03	1.18	+0.03	-2.51	-0.08
			Elementary Grades	1.86	+0.06	1.01	+0.03	0.17	+0.01
		Gender	Females	2.44	+0.08	1.02	+0.03	-0.18	-0.01
			Males	0.76	+0.02	1.19	+0.04	-2.02	-0.06
		Special Education Status	Not Special Education	1.48	+0.05	1.62	+0.05	-0.99	-0.03
			Special Education	2.79	+0.09	-1.52	-0.04	-1.07	-0.03
		Baseline Achievement	Low 25% at Baseline	3.17	+0.10	0.25	+0.01	0.95	+0.03
			Top 75% at Baseline	1.18	+0.04	1.38	+0.04	-1.72	-0.05
Math	i-Ready	Grade Level	Elementary Grades	1.11	+0.03**	3.54	+0.09	4.38	+0.12
			Middle Grades	-6.91	-0.21	2.97	+0.08	1.56	+0.04
		Gender	Females	1.03	+0.03	1.62	+0.04	2.22	+0.06
			Males	-1.52	-0.05	5.29	+0.14	3.70	+0.10

Subject	Test	Category	Subgroup	1-Year results				2-Year results	
				SY1617		SY1718		SY1718	
				Impact	Effect Size	Impact	Effect Size	Impact	Effect Size
		Special Education Status	Special Education	-0.79	-0.02	1.83	+0.05	4.81	+0.13
			Not Special Education	0.06	0.00	3.52	+0.09	2.49	+0.07
		Baseline Achievement	Low 25% at Baseline	2.18	+0.07	2.46	+0.06	4.34	+0.11
			Top 75% at Baseline	-0.86	-0.03	3.48	+0.09	2.41	+0.06
	PARCC	Grade Level	Elementary Grades	0.17	+0.01	5.57	+0.18	1.13	+0.04
			Middle Grades	-0.44	-0.01	1.01	+0.03	-0.76	-0.02
		Gender	Females	0.55	+0.02	4.07	+0.13	3.30	+0.11
			Males	-0.56	-0.02	1.66	+0.05	-3.67	-0.12
		Special Education Status	Special Education	0.60	+0.02	4.62	+0.15	5.16	+0.17
			Not Special Education	-0.05	0.00	2.70	+0.09	-1.00	-0.03
		Baseline Achievement	Top 75% at Baseline	0.05	0.00	1.93	+0.06	-0.24	-0.01
			Low 25% at Baseline	0.09	0.00	6.31	+0.20	1.05	+0.03

Table note: 1. **p<.01. 2. The models also controlled for student grade level, prior achievement, and blocking variables used in random assignment (charter school status, school type, pilot study participation, school proportion of low-income and Black students, and whether the school served more than 25% Latino students). 3. The statistical significance was calculated by conducting a test to see if treatment + treatment*interaction==0 after running the relevant model. 4. Multiple comparison corrections were applied to p-values using the Bonferroni procedure.

Differential achievement results: types and severity of refractive errors.

Category of refractive error.

D4. Interaction terms for categories of refractive error.

Subj	Test	Coefficient	1-Year results				2-Year results	
			SY1617		SY1718		SY1718	
			Impact (SE)	p Value	Impact (SE)	p Value	Impact (SE)	p Value
Year			SY 16-17		SY 17-18		SY 17-18	
ELA	i-Ready	treat:hypopia	0.32 (5.59)	.99	19.76 (10.09)	.99	16.07 (10.10)	.99
		treat:myopia	-1.28 (3.75)	.99	12.37 (6.45)	.99	6.50 (6.62)	.99
	PARCC	treat:hypopia	0.57 (3.16)	.99	0.47 (4.49)	.99	2.59 (4.46)	.99
		treat:myopia	2.47 (2.08)	.99	1.68 (3.05)	.99	2.61 (3.10)	.99
Math	i-Ready	treat:hypopia	-2.15 (3.49)	.99	-4.37 (5.48)	.99	-1.60 (5.16)	.99
		treat:myopia	0.77 (2.37)	.99	-2.49 (3.59)	.99	-0.38 (3.43)	.99
	PARCC	treat:hypopia	-0.29 (3.42)	.99	5.78 (4.41)	.99	6.84 (4.19)	.99
		treat:myopia	3.95 (2.30)	.99	4.92 (3.01)	.99	7.46 (2.92)	.64

Table note: 1. The numbers in parentheses are the standard errors. 2. The models also controlled for student grade level, prior achievement, and blocking variables used in random assignment (charter school status, school type, pilot study participation, school proportion of low-income and Black students, and whether the school served more than 25% Latino students), with no astigmatism as the reference group. 3. Multiple comparison corrections were applied to p-values using the Bonferroni procedure. 4. Comparisons are being made to the treatment impact for a student with emmetropia.

D5. Adjusted mean impacts and effect sizes by category of refractive error.

Subject	Test	Subgroup	1-year results								2-year results			
			SY 16-17				SY 17-18				SY 17-18			
			Mean Ctrl	Impact	Effect Size	p Value	Mean Ctrl	Impact	Effect Size	p Value	Mean Ctrl	Impact	Effect Size	p Value
ELA	i-Ready	Emmetropia	511.32	5.76	+0.10	.99	537.32	2.40	+0.04	.99	534.55	1.8	+0.03	.99
		Hyperopia	513.62	6.08	+0.11	.99	521.80	22.16	+0.35	.99	519.02	17.9	+0.29	.99
		Myopia	515.69	4.48	+0.08	.99	529.75	14.77	+0.23	.32	526.90	8.3	+0.13	.99
	PARCC	Emmetropia	710.38	0.24	+0.01	.99	716.30	3.68	+0.11	.99	713.96	-1.3	-0.04	.99
		Hyperopia	711.10	-1.91	-0.06	.99	721.00	-0.69	-0.02	.99	717.73	-2.9	-0.09	.99
		Myopia	712.10	1.01	+0.03	.99	720.40	1.19	+0.04	.99	718.14	-1.7	-0.05	.99
Math	i-Ready	Emmetropia	448.35	-0.76	-0.02	.99	449.56	3.62	+0.09	.99	449.03	3.1	+0.08	.99
		Hyperopia	446.16	-0.19	-0.01	.99	447.99	4.09	+0.11	.99	446.96	5.6	+0.15	.99
		Myopia	447.79	1.71	+0.05	.99	448.81	5.30	+0.14	.99	448.72	5.7	+0.15	.99
	PARCC	Emmetropia	714.01	-2.44	-0.08	.99	716.52	0.62	+0.02	.99	714.70	-4.3	-0.14	.99
		Hyperopia	713.89	-2.73	-0.09	.99	709.99	6.40	+0.20	.99	707.87	2.5	+0.08	.99
		Myopia	713.37	1.51	+0.05	.99	712.26	5.54	+0.17	.99	710.60	3.2	+0.10	.99

Table note. 1. Effect sizes are experimental minus control means divided by the pooled standard deviation. 2. The models also controlled for student grade level, prior achievement, and blocking variables used in random assignment (charter school status, school type, pilot study participation, school proportion of low-income and Black students, and whether the school served more than 25% Latino students). 3. Multiple comparison corrections were applied to p-values using the Bonferroni procedure.

Severity of refractive error.

D6. Interaction terms for severity of refractive error.

Subject	Test	Coefficient	1-year results				2-year results	
			SY 16-17		SY 17-18		SY 17-18	
			Impact (SE)	p Value	Impact (SE)	p Value	Impact (SE)	p Value

Subject	Test	Coefficient	1-year results				2-year results	
			SY 16-17		SY 17-18		SY 17-18	
			Impact (SE)	p Value	Impact (SE)	p Value	Impact (SE)	p Value
ELA	i-Ready	treat:hyperopia_1	1.49 (5.87)	.99	18.22 (10.80)	.99	11.96 (10.64)	.99
		treat:hyperopia_2	-6.33 (12.83)	.99	21.75 (21.64)	.99	37.05 (23.08)	.99
		treat:myopia_1	-1.01 (3.84)	.99	13.50 (6.61)	.99	7.38 (6.76)	.99
		treat:myopia_2	-4.43 (6.02)	.99	4.59 (9.45)	.99	-0.22 (9.72)	.99
Math		treat:hyperopia_1	1.64 (3.31)	.99	-0.38 (4.94)	.99	2.81 (4.85)	.99
		treat:hyperopia_2	-7.94 (7.43)	.99	3.50 (7.84)	.99	0.16 (8.06)	.99
		treat:myopia_1	2.61 (2.13)	.99	1.56 (3.12)	.99	2.60 (3.17)	.99
		treat:myopia_2	0.13 (3.31)	.99	3.49 (4.63)	.99	2.90 (4.76)	.99
ELA	PARCC	treat:hyperopia_1	-1.14 (3.68)	.99	-5.32 (5.79)	.99	-2.16 (5.42)	.99
		treat:hyperopia_2	-7.00 (7.72)	.99	-4.54 (12.31)	.99	-3.47 (11.72)	.99
		treat:myopia_1	1.23 (2.42)	.99	-2.23 (3.68)	.99	-0.20 (3.51)	.99
		treat:myopia_2	-0.33 (3.71)	.99	-6.09 (5.23)	.99	-4.00 (5.03)	.99
Math		treat:hyperopia_1	-0.75 (3.60)	.99	6.40 (4.78)	.99	9.78 (4.51)	.99

Subject	Test	Coefficient	1-year results				2-year results	
			SY 16-17		SY 17-18		SY 17-18	
			Impact (SE)	p Value	Impact (SE)	p Value	Impact (SE)	p Value
		treat:hyperopia_2	1.46 (7.59)	.99	3.50 (8.22)	.99	-6.00 (7.76)	.99
		treat:myopia_1	3.65 (2.36)	.99	4.77 (3.08)	.99	7.15 (2.98)	.99
		treat:myopia_2	5.18 (3.64)	.99	6.25 (4.51)	.99	9.51 (4.44)	.99

Table note: 1. The numbers in parentheses are the standard errors. 2. The models also controlled for student grade level, prior achievement, and blocking variables used in random assignment (charter school status, school type, pilot study participation, school proportion of low-income and Black students, and whether the school served more than 25% Latino students). 3. Multiple comparison corrections were applied to p-values using the Bonferroni procedure. 4. Comparisons are being made to the treatment impact for a student with emmetropia.

D7. Adjusted mean impacts and effect sizes by severity of refractive error.

Subject	Test	Subgroup	1-year results								2-year results			
			SY 16-17				SY 17-18				SY 17-18			
			Mean Ctrl	Impact	Effect Size	p Value	Mean Ctrl	Impact	Effect Size	p Value	Mean Ctrl	Impact	Effect Size	p Value
ELA	i-Ready	Emmetropia	511.37	5.82	+0.10	.99	537.20	2.57	+0.04	.99	534.40	2.45	+0.04	.99
		Hyperopia 1	512.01	7.30	+0.13	.99	521.72	20.78	+0.33	.99	518.92	14.41	+0.23	.99
		Hyperopia 2	523.50	-0.51	-0.01	.99	526.34	24.32	+0.37	.99	523.63	39.50	+0.61	.99
		Myopia 1	515.84	4.80	+0.08	.99	528.70	16.07	+0.25	.26	525.90	9.83	+0.16	.99
		Myopia 2	515.17	1.39	+0.02	.99	535.48	7.16	+0.11	.99	532.14	2.23	+0.04	.99
	PARCC	Emmetropia	710.49	0.06	0.00	.99	716.05	3.95	+0.12	.99	713.73	-1.03	-0.03	.99
		Hyperopia 1	710.02	-1.09	-0.03	.99	720.91	-1.37	-0.04	.99	717.91	-3.19	-0.10	.99
		Hyperopia 2	717.62	-6.95	-0.21	.99	724.83	-0.59	-0.02	.99	719.74	-4.50	-0.14	.99
		Myopia 1	711.91	1.28	+0.04	.99	720.16	1.72	+0.05	.99	717.87	-1.23	-0.04	.99

Subject	Test	Subgroup	1-year results								2-year results			
			SY 16-17				SY 17-18				SY 17-18			
			Mean Ctrl	Impact	Effect Size	p Value	Mean Ctrl	Impact	Effect Size	p Value	Mean Ctrl	Impact	Effect Size	p Value
		Myopia 2	713.21	-0.28	-0.01	.99	721.99	-2.14	-0.06	.99	719.82	-5.02	-0.16	.99
Math	i-Ready	Emmetropia	448.34	-0.74	-0.02	.99	449.64	3.49	+0.09	.99	449.10	2.89	+0.08	.99
		Hyperopia 1	446.06	0.90	+0.03	.99	448.93	3.11	+0.08	.99	447.94	5.70	+0.15	.99
		Hyperopia 2	446.69	-8.68	-0.25	.99	445.01	6.99	+0.18	.99	443.78	3.05	+0.08	.99
		Myopia 1	447.85	1.87	+0.06	.99	448.71	5.05	+0.13	.99	448.57	5.49	+0.15	.99
		Myopia 2	447.48	-0.61	-0.02	.99	449.52	6.98	+0.18	.99	449.78	5.79	+0.15	.99
	PARCC	Emmetropia	713.93	-2.36	-0.08	.99	716.51	0.58	+0.02	.99	714.67	-4.48	-0.15	.99
		Hyperopia 1	714.71	-3.11	-0.10	.99	709.72	6.98	+0.22	.99	707.51	5.29	+0.17	.99
		Hyperopia 2	709.17	-0.90	-0.03	.99	710.77	4.08	+0.13	.99	708.76	-10.48	-0.33	.99
		Myopia 1	713.18	1.30	+0.04	.99	712.47	5.35	+0.17	.99	710.79	2.67	+0.09	.99
		Myopia 2	714.63	2.83	+0.09	.99	710.98	6.84	+0.21	.99	709.35	5.03	+0.16	.99

Table note. 1. Effect sizes are experimental minus control means divided by the pooled standard deviation. 2. The models also controlled for student grade level, prior achievement, and blocking variables used in random assignment (charter school status, school type, pilot study participation, school proportion of low-income and Black students, and whether the school served more than 25% Latino students). 3. Multiple comparison corrections were applied to p-values using the Bonferroni procedure.

Astigmatism.

D8. Interaction terms for astigmatism.

Subject	Test	Coefficient	1-year results				2-year results	
			SY 16-17		SY 17-18		SY 17-18	
			Impact (SE)	p Value	Impact (SE)	p Value	Impact (SE)	p Value
ELA	i-Ready	treat:Astigmatism	0.69 (3.26)	.99	-15.44 (5.43)	<.01	-9.33 (5.43)	.99

Subject	Test	Coefficient	1-year results				2-year results	
			SY 16-17		SY 17-18		SY 17-18	
			Impact (SE)	p Value	Impact (SE)	p Value	Impact (SE)	p Value
Math	PARCC	treat:Astigmatism	-2.46 (1.82)	.99	-3.33 (2.53)	.99	-4.86 (2.51)	.99
ELA		treat:Astigmatism	2.54 (2.03)	.99	-0.30 (2.96)	.99	1.97 (2.77)	.99
Math		treat:Astigmatism	-0.04 (1.98)	.99	-4.18 (2.48)	.99	-3.28 (2.36)	.99

Table note: 1. The numbers in parentheses are the standard errors. 2. The models also controlled for student grade level, prior achievement, and blocking variables used in random assignment (charter school status, school type, pilot study participation, school proportion of low-income and Black students, and whether the school served more than 25% Latino students). 3. Multiple comparison corrections were applied to p-values using the Bonferroni procedure. 4. Comparisons are being made to the treatment impact for a student with no astigmatism.

D9. Adjusted mean impacts and effect sizes for astigmatism.

Subject	Test	Subgroup	1-year results								2-year results			
			SY 16-17				SY 17-18				SY 17-18			
			Mean Ctrl	Impact	Effect Size	p Value	Mean Ctrl	Impact	Effect Size	p Value	Mean Ctrl	Impact	Effect Size	p Value
ELA	i-Ready	No Astigmatism	511.32	5.76	+0.10	.99	537.32	2.40	+0.04	.99	534.55	1.85	+0.03	.99
		Astigmatism	509.15	6.45	+0.11	.99	543.60	-13.04	-0.21	.99	540.88	-7.48	-0.12	.99
	PARCC	Astigmatism	709.38	2.78	+0.09	.99	714.30	3.38	+0.10	.99	711.89	0.66	+0.02	.99
		No Astigmatism	710.38	0.24	+0.01	.99	716.30	3.68	+0.11	.99	713.96	-1.31	-0.04	.99
Math	i-Ready	Astigmatism	449.74	-3.22	-0.10	.99	452.23	0.29	+0.01	.99	451.41	-1.80	-0.05	.99

Subject	Test	Subgroup	1-year results								2-year results			
			SY 16-17				SY 17-18				SY 17-18			
			Mean Ctrl	Impact	Effect Size	p Value	Mean Ctrl	Impact	Effect Size	p Value	Mean Ctrl	Impact	Effect Size	p Value
		No Astigmatism	448.35	-0.76	-0.02	.99	449.56	3.62	+0.09	.99	449.03	3.06	+0.08	.99
	PARCC	No Astigmatism	714.01	-2.44	-0.08	.99	716.52	0.62	+0.02	.99	714.70	-4.31	-0.14	.99
	PARCC	Astigmatism	714.32	-2.48	-0.08	.99	719.54	-3.56	-0.11	.99	717.86	-7.59	-0.25	.99

Table note. 1. Effect sizes are experimental minus control means divided by the pooled standard deviation. 2. The models also controlled for student grade level, prior achievement, and blocking variables used in random assignment (charter school status, school type, pilot study participation, school proportion of low-income and Black students, and whether the school served more than 25% Latino students). 3. Multiple comparison corrections were applied to p-values using the Bonferroni procedure. 4. Comparisons are being made to the treatment impact for a student with no astigmatism.

Severity of astigmatism.

D10. Interaction terms for severity of astigmatism.

Subject	Test	Coefficient	1-year results				2-year results	
			SY 16-17		SY 17-18		SY 17-18	
			Impact (SE)	p Value	Impact (SE)	p Value	Impact (SE)	p Value
ELA	i-Ready	treat:astig_1	0.16 (3.40)	.99	-16.33 (5.63)	<.01	-11.39 (5.65)	.99
		treat:astig_3	5.97 (8.05)	.99	-0.45 (14.29)	.99	4.14 (13.70)	.99
Math		treat:astig_1	-3.00 (1.89)	.99	-2.79 (2.64)	.99	-4.43 (2.63)	.99
		treat:astig_3	3.56 (4.43)	.99	-8.19 (6.06)	.99	-5.77 (5.88)	.99

Subject	Test	Coefficient	1-year results				2-year results	
			SY 16-17		SY 17-18		SY 17-18	
			Impact (SE)	p Value	Impact (SE)	p Value	Impact (SE)	p Value
ELA	PARCC	treat:astig_1	3.52 (2.11)	.99	-1.26 (3.09)	.99	0.92 (2.88)	.99
		treat:astig_3	-4.38 (4.81)	.99	10.19 (7.37)	.99	13.17 (6.77)	.99
Math		treat:astig_1	-0.64 (2.06)	.99	-3.76 (2.60)	.99	-2.45 (2.46)	.99
		treat:astig_3	5.05 (4.65)	.99	-7.58 (5.84)	.99	-5.60 (5.48)	.99

Table note: 1. The numbers in parentheses are the standard errors. 2. The models also controlled for student grade level, prior achievement, and blocking variables used in random assignment (charter school status, school type, pilot study participation, school proportion of low-income and Black students, and whether the school served more than 25% Latino students). 3. Multiple comparison corrections were applied to p-values using the Bonferroni procedure. 4. Comparisons are being made to the treatment impact for a student with no astigmatism.

D11. Adjusted mean impacts and effect sizes by severity of astigmatism.

Subject	Test	Subgroup	1-year results								2-year results			
			SY 16-17				SY 17-18				SY 17-18			
			Mean Ctrl	Impact	Effect Size	p Value	Mean Ctrl	Impact	Effect Size	p Value	Mean Ctrl	Impact	Effect Size	p Value
ELA	i-Ready	Astigmatism 0	511.37	5.82	+0.10	.99	537.20	2.57	+0.04	.99	534.40	2.45	+0.04	.99
		Astigmatism 1	509.14	5.98	+0.11	.99	543.76	-13.77	-0.22	.99	541.09	-8.94	-0.14	.99
		Astigmatism 3	508.55	11.79	+0.21	.99	534.57	2.11	+0.03	.99	531.75	6.58	+0.11	.99

Subject	Test	Subgroup	1-year results								2-year results			
			SY 16-17				SY 17-18				SY 17-18			
			Mean Ctrl	Impact	Effect Size	p Value	Mean Ctrl	Impact	Effect Size	p Value	Mean Ctrl	Impact	Effect Size	p Value
	PARCC	Astigmatism 0	710.49	0.06	0.00	.99	716.05	3.95	+0.12	.99	713.73	-1.03	-0.03	.99
		Astigmatism 1	708.90	3.58	+0.11	.99	714.90	2.69	+0.08	.99	712.50	-0.11	0.00	.99
		Astigmatism 3	713.28	-4.33	-0.14	.99	704.82	14.14	+0.41	.99	702.56	12.14	+0.38	.99
Math	i-Ready	Astigmatism 0	448.34	-0.74	-0.02	.99	449.64	3.49	+0.09	.99	449.10	2.89	+0.08	.99
		Astigmatism 1	449.81	-3.74	-0.11	.99	452.11	0.70	+0.02	.99	451.25	-1.53	-0.04	.99
		Astigmatism 3	449.14	2.82	+0.09	.99	453.89	-4.70	-0.12	.99	452.80	-2.88	-0.08	.99
	PARCC	Astigmatism 0	713.93	-2.36	-0.08	.99	716.51	0.58	+0.02	.99	714.67	-4.48	-0.14	.99
		Astigmatism 1	714.79	-2.99	-0.10	.99	719.59	-3.17	-0.10	.99	717.82	-6.93	-0.22	.99
		Astigmatism 3	709.30	2.69	+0.09	.99	719.86	-7.00	-0.22	.99	718.49	-10.08	-0.32	.99

Table note. 1. Effect sizes are experimental minus control means divided by the pooled standard deviation. 2. The models also controlled for student grade level, prior achievement, and blocking variables used in random assignment (charter school status, school type, pilot study participation, school proportion of low-income and Black students, and whether the school served more than 25% Latino students). 3. Multiple comparison corrections were applied to p-values using the Bonferroni procedure.

Visual impairment.

D12. Interaction terms for visual impairment.

Subject	Test	Coefficient	1-year results				2-year results	
			SY 16-17		SY 17-18		SY 17-18	
			Impact (SE)	p Value	Impact (SE)	p Value	Impact (SE)	p Value
ELA	i-Ready	treat:impair_1	-1.23 (4.48)	.99	-10.36 (7.44)	.99	-4.40 (7.37)	.99
		treat:impair_2	-2.07 (4.21)	.99	4.40 (6.63)	.99	0.70 (6.66)	.99
		treat:impair_3	-0.36 (9.43)	.99	5.30 (13.93)	.99	2.49 (16.39)	.99
Math		treat:impair_1	2.61 (2.50)	.99	1.25 (3.59)	.99	3.06 (3.48)	.99
		treat:impair_2	2.69 (2.36)	.99	1.29 (3.15)	.99	1.49 (3.21)	.99
		treat:impair_3	-4.58 (5.12)	.99	-11.73 (6.32)	.99	-11.26 (7.62)	.99
ELA	PARCC	treat:impair_1	-2.34 (2.81)	.99	-0.27 (4.03)	.99	-1.53 (3.82)	.99
		treat:impair_2	-0.11 (2.63)	.99	2.60 (3.64)	.99	4.01 (3.47)	.99
		treat:impair_3	9.95 (5.74)	.99	-9.90 (7.26)	.99	-8.25 (8.00)	.99
Math		treat:impair_1	0.66 (2.73)	.99	0.70 (3.50)	.99	-0.77 (3.32)	.99
		treat:impair_2	2.84 (2.58)	.99	3.74 (3.12)	.99	2.34 (3.04)	.99

	treat:impair_3	5.05 (5.65)	.99	-1.22 (6.09)	.99	-4.77 (7.43)	.99

Table note: 1. The numbers in parentheses are the standard errors. 2. The models also controlled for student grade level, prior achievement, and blocking variables used in random assignment (charter school status, school type, pilot study participation, school proportion of low-income and Black students, and whether the school served more than 25% Latino students). 3. Multiple comparison corrections were applied to p-values using the Bonferroni procedure. 4. Comparisons are being made to the treatment impact for a student with no visual impairment.

D13. Adjusted mean impacts and effect sizes by level of visual impairment.

Subject	Test	Subgroup	1-year results								2-year results			
			SY 16-17				SY 17-18				SY 17-18			
			Mean Ctrl	Impact	Effect Size	p Value	Mean Ctrl	Impact	Effect Size	p Value	Mean Ctrl	Impact	Effect Size	p Value
ELA	i-Ready	Impair_0	512.79	5.66	+0.10	.99	531.80	8.36	+0.13	.99	528.90	5.32	+0.09	.99
		Impair_1	516.25	4.43	+0.08	.99	536.75	-2.01	-0.03	.99	534.03	0.91	+0.01	.99
		Impair_2	515.75	3.59	+0.06	.99	530.87	12.75	+0.20	.99	529.05	6.01	+0.10	.99
		Impair_3	508.45	5.30	+0.09	.99	529.04	13.66	+0.22	.99	526.87	7.81	+0.12	.99
	PARCC	Impair_0	710.56	1.54	+0.05	.99	718.52	0.88	+0.03	.99	716.01	-1.56	-0.05	.99
		Impair_1	713.19	-0.79	-0.02	.99	722.62	0.61	+0.02	.99	719.58	-3.09	-0.10	.99
		Impair_2	712.30	1.43	+0.04	.99	716.67	3.48	+0.10	.99	714.62	2.45	+0.08	.99
		Impair_3	709.48	11.50	+0.35	.99	729.90	-9.02	-0.26	.99	728.22	-9.81	-0.30	.99

Subject	Test	Subgroup	1-year results								2-year results			
			SY 16-17				SY 17-18				SY 17-18			
			Mean Ctrl	Impact	Effect Size	p Value	Mean Ctrl	Impact	Effect Size	p Value	Mean Ctrl	Impact	Effect Size	p Value
Math	i-Ready	Impair_0	448.60	-0.77	-0.02	.99	450.05	3.36	+0.09	.99	449.66	2.62	+0.07	.99
		Impair_1	447.28	1.85	+0.06	.99	447.30	4.61	+0.12	.99	446.68	5.68	+0.15	.99
		Impair_2	446.59	1.92	+0.06	.99	448.89	4.65	+0.12	.99	448.84	4.10	+0.11	.99
		Impair_3	454.15	-5.35	-0.16	.99	463.72	-8.37	-0.22	.99	463.40	-8.64	-0.22	.99
	PARCC	Impair_0	713.24	-0.59	-0.02	.99	713.93	2.31	+0.07	.99	712.20	-0.21	-0.01	.99
		Impair_1	714.49	0.08	0.00	.99	716.35	3.02	+0.09	.99	714.62	-0.98	-0.03	.99
		Impair_2	714.69	2.25	+0.07	.99	711.89	6.05	+0.19	.99	710.26	2.14	+0.07	.99
		Impair_3	712.29	4.46	+0.14	.99	715.41	1.10	+0.03	.99	714.43	-0.22	-0.01	.99

Table note. 1. Effect sizes are experimental minus control means divided by the pooled standard deviation. 2. The models also controlled for student grade level, prior achievement, and blocking variables used in random assignment (charter school status, school type, pilot study participation, school proportion of low-income and Black students, and whether the school served more than 25% Latino students). 3. Multiple comparison corrections were applied to p-values using the Bonferroni procedure.

Results for attendance.

D14.

Year	School N	Student N	Average days present for comparison students	Average V4B difference	Effect Size	p Value

			1-year results			
SY 16-17	113	1582	166.92	-0.96 (1.05)	-0.06	.36
SY 17-18	78	1207	164.32	-0.13 (1.83)	-0.01	.94
			2-year results			
SY 17-18	77	1144	164.14	-2.20 (1.62)	-0.10	.18

Table note. 1. Effect sizes are experimental minus control means divided by the pooled standard deviation. 2. The models also controlled for student grade level and blocking variables used in random assignment (charter school status, school type, pilot study participation, school proportion of low-income and Black students, and whether the school served more than 25% Latino students).