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Information for vision: Experimental evidence on nudging low-income students to wear eyeglasses[☆]

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ABSTRACT

Inaccurate information and biased beliefs about myopia and glasses-wearing can lead to low take-up of eyeglasses among myopic students. This paper provides experimental evidence on behavioral barriers affecting students' belief updating and stated preferences regarding glasses-wearing. We conducted a lab-in-the-field experiment with 8262 middle school students in a remote, underdeveloped county in China to test four targeted information nudges. Among myopic students without glasses, information on glasses prices and the short-term academic benefits of wearing glasses was most effective. The nudges worked by updating beliefs or increasing the salience of myopia and glasses-wearing, with substantial heterogeneity by myopia duration, academic performance, and peer groups. Cost–benefit analysis shows that targeted nudges remain cost-effective even under conservative take-up assumptions. Our results provide evidence of the importance of precise, personalized information nudges in improving students' educational input and academic achievement.

1. Introduction

Myopia is a leading cause of visual disability that can be corrected by wearing glasses. Studies reveal that a significant portion of low-income students with myopia do not wear glasses (Ethan & Basch, 2008; Holguin et al., 2006; Ma et al., 2014; Wang et al., 2015), which may affect their learning and compound social inequality. An emerging literature documents that improving the availability and affordability of eyeglasses, such as providing free eyeglasses (Glewwe et al., 2016; Ma et al., 2014) and vouchers (Guan et al., 2023), could significantly enhance the educational outcomes of low-income students with myopia. However, the effectiveness of those interventions was limited by the low take-up among students, even if eyeglasses were provided for free (Glewwe et al., 2016; Ma et al., 2014). According to a meta-analysis, those interventions achieved an overall take-up rate of 53.11%, suggesting that only about half of the students being treated actually wore eyeglasses (Wu et al., 2023). Even though some research complements their experiments with additional interventions to improve the take-up, including educational campaigns (Sylvia et al., 2022; Zhang et al., 2021) or using deadlines (Guan et al., 2023), few have discussed the underlying mechanisms for the low take-up. This raises the question of what barriers result in the low take-up.

Considering the high returns to wearing glasses, behavioral barriers might contribute to the low take-up of eyeglasses. A vast literature in behavioral economics documents the negative effects of behavioral biases on individuals' decision-making. In particular, individuals with low socioeconomic status (SES) are more susceptible to behavioral biases (Lavecchia et al., 2016). In our context, students from less-educated or low-income families may face limited access to accurate information about the costs and benefits of wearing eyeglasses, hold incorrect beliefs on the need for vision correction, and are surrounded by an environment with greater stigma and entrenched social norms (Damgaard & Nielsen, 2018; Lavecchia et al., 2016). These factors combined may prevent them from wearing glasses, even if glasses were given for free.

This paper provides new experimental evidence to understand what behavioral barriers affect low-income students' decision-making about

☆ The survey experiment reported in this paper was organized and implemented in 2022 by the local government in Yun County (Yun County Department of Education) and it was exempted from IRB request. All subjects (and their parents) have been informed of the nature of the experiment and gave their consents before the experiment. We did not register for pre-analysis because the experiment was designed in 2021 when the pre-analysis was not compulsory at that time.

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glasses-wearing. We use an informational nudge that targets specific behavioral barriers to examine the effects of different information components on students' willingness to wear glasses. To this end, we conducted a large-scale randomized experiment across 20 middle schools in a remote and underdeveloped county in Yunnan, China. A total of 8262 7th and 8th graders in these schools participated in the experiment, which was randomized at the individual level.

Crucially, our experimental design tests the hypothesis that informational barriers affect not only private behavior but also social norms. We measure students' responsiveness through two distinct outcomes: (1) their personal willingness to wear glasses, which captures the private utility and cost–benefit calculation; and (2) their willingness to encourage myopic friends to wear glasses. This second outcome is conceptually distinct: it serves as a proxy for willingness to engage in norm-shifting behaviors. By measuring public endorsement, we aim to capture whether the information nudges successfully reduce the social stigma often associated with glasses-wearing (e.g., fear of ridicule or teasing), transforming it from a hidden disability into a socially recommended practice.

We examine whether an information nudge can effectively improve students' stated willingness to wear glasses, and if so, which type of information is the most effective. Throughout the paper, we are careful to distinguish belief updating and stated preferences—which our experiment is designed to measure—from actual eyeglass adoption, which depends on additional structural constraints that we explore in a survey. We find that our information nudges have a positive effect on students' stated willingness to wear glasses. When considering the whole sample, information about the short-term benefits of wearing glasses (T1) was the most effective overall, increasing the willingness to wear glasses by 5.6 percentage points (pp) and the willingness to encourage friends to wear glasses by 5.8 pp. For myopic students without glasses, the most effective information was about the glasses prices (T4), which increased the willingness to wear glasses by 6.9 pp.

Following the baseline results, we examine the possible behavioral mechanisms by which the information nudge affected the willingness. By dividing students into subgroups based on their baseline beliefs and test scores, we were able to understand whether the information nudges worked by updating beliefs or increasing the salience of issues related to myopia and glasses-wearing. We find that (1) T1 worked by updating students' beliefs about the impact of glasses-wearing on their studies, (2) T2 worked by increasing the salience of the long-term health benefits and future consequences of wearing glasses, (3) T3 worked by updating beliefs about the prevalence of myopia, and (4) T4 worked by updating beliefs about the prices of standard glasses.

In order to determine the most effective nudge that promotes the glasses-wearing willingness, we then proceed to explore the optimal combination of the type of information and the subgroup among myopic students. We do so by examining the heterogeneous treatment effects in three dimensions: myopia duration, academic performance, and peer groups. The nudge effects vary substantially with students' myopia duration and academic performance. Information nudge was more effective for those with myopia duration within one year or who have above-median test scores, compared with those with myopia duration beyond one year or who have below-median test scores. Additionally, the heterogeneity in peer groups show that myopic students who had more classmates wearing glasses were more willing to wear glasses after receiving the information about glasses prices, while greater exposure to high-achieving classmates complemented the overall nudge effects.

To show that our informational nudge was cost-effective, we begin by measuring the benefits of glasses-wearing regarding its impacts on students' academic performance. Using our cross-sectional administrative data on students' test scores, wearing glasses was shown to have a positive 0.131 SD correlation with Mathematics test scores and a positive 0.111 SD correlation with the average test scores, both of which offset the negative correlation between myopia and the corresponding test scores. We also use a nationally representative dataset (CEPS) to shed light on the causal effects of glasses-wearing on students' test scores and to complement the correlation results. We find that wearing glasses after developing myopia leads to consistent improvements in students' test scores across various subjects, and entirely counteracts the negative effects brought by myopia on test scores.

Finally, we conducted a cost–benefit analysis. By applying the nudge effects from our results, we calculated the monetary benefits of wearing glasses. Subtracting the associated costs of buying eyeglasses and delivering the nudge, the net benefit could be at least $1124 in total, or $1.124 per capita, for 1000 myopic minority girls without glasses. The total net benefit would be approximately $674 for our project, based on the per capita net benefit of $1.124. The nudge's cost-effectiveness remains valid after adjusting for the take-up rate, eyeglasses price and nudge effect.

This paper contributes to our understanding of identifying specific behavioral biases that prevent low-income students from making optimal decisions to wear eyeglasses. Previous papers on vision health mostly ignore the behavioral barriers to eyeglass adoption. In a meta-analysis by Wu et al. (2023), the authors reviewed seven studies that identified the factors responsible for low eyeglasses adoption. These factors include the severity of the refractive error, demographic and economic factors, such as children's age, sex, and family income. But none of those involved behavioral elements.

Some studies employed informational interventions to improve eyeglasses adoption. For example, Sylvia et al. (2022) and Zhang et al. (2021) both launched health education campaigns informing students of the benefits of wearing eyeglasses, yet the education campaigns functioned as a single treatment arm that combined information of various topics. Unlike our design, their experiments did not use multiple treatment arms, each delivering specialized information about a specific topic, to separately estimate the effects of specialized information. For another example, Guan et al. (2023) and Zhang et al. (2022) used message framing and voucher deadlines to improve the effectiveness of glasses adoption among students, but they did not explore the behavioral barriers to glasses-wearing. Compared to the prior research, our experiment shows the importance of information that targets specific behavioral barriers in improving students' decisions to wear glasses.

We also relate to the literature which explores the behavioral mechanisms of information nudges. Recent studies revealed that informational interventions may work through increasing the salience of information provided to subjects apart from the traditional mechanism of updating beliefs (Bettinger et al., 2021; Ma et al., 2023). According to Bettinger et al. (2021), if information are made salient, agents might undertake actions pertaining to that information to a greater extent. Our results validate the theory by examining the behavioral mechanisms of the information nudges. We find that the information about long-term benefits (T2) affected high-achieving students more effectively by increasing the salience of the information.

Finally, the cost-effectiveness of the interventions designed to promote glasses-wearing holds significant policy implications. Most interventions in prior research took the form of providing free eyeglasses or vouchers, which is expensive and possibly unsustainable due to the combination of substantial costs and low take-up rates among students. While Guan et al. (2023) and Sylvia et al. (2022) managed to improve the effectiveness of their interventions by increasing the take-up rates, their interventions required a relatively long duration and incurred considerable expenses, limiting their policy applicability. We provide evidence that even a light-touch informational nudge can significantly improve the willingness to wear glasses.

The rest of the paper is organized as follows: Section 2 describes the background of the prevalence of myopia without wearing glasses and behavioral biases. Section 3 presents the interventions and the randomized experimental design. Section 4 reports the experiment results and discusses the behavioral mechanisms by which the information nudge works, as well as the heterogeneous treatment effects. Section 5 provides the cost–benefit analysis. Section 6 concludes.

2. Background: Low take-up of eyeglasses among low-income students

Approximately 2.6 billion people have myopia of which 312 million are under the age of 19 (World Health Organization, 2019). In China, about 52.7 percent of children and adolescents had poor vision in 2020, among which the proportions of primary, middle, and high school students were 35.6%, 71.1%, and 80.5%, respectively (Ministry of Education of China 2021).[1]

This visual disorder can significantly impact students' educational outcomes (World Health Organization, 2019), including their development of motor skills (Warren, 1994), interaction with peers (Rainey et al., 2016), engagement in physical activities (Ethan & Basch, 2008), mental health (Yi et al., 2015), and personal identity (Oh et al., 2004). This visual problem is also a critical factor affecting education equity. The disorder has brought about a disproportionate burden on low socioeconomic status (SES) students with an estimated rate of unaddressed myopia 80% higher in low- and middle-income areas than in high-income areas (Fricke et al., 2018). However, about 38%–85% of rural students with visual impairment do not wear eyeglasses or even have taken a vision test (Glewwe et al., 2016).

Since myopia is irreversible, eyeglasses are a type of commonly used treatment, which can significantly improve refractive errors and slow the progression toward vision impairment (World Health Organization, 2019). Several experimental studies have investigated the effects of the availability and affordability of eyeglasses for improving education outcomes (Fricke et al., 2012; Graham, 2017; Ma et al., 2014). For example, by offering 7th and 8th graders free eyeglasses in 16 schools in Yulin Prefecture, Shaanxi Province, China, Nie et al. (2020) found a 0.14 standard deviation increase in test scores and a two percentage point decrease in dropouts, compared to students who were only provided with myopic prescriptions. In Gansu Province, China, wearing eyeglasses increased test scores by 0.16 to 0.22 standard deviations for 4th, 5th, and 6th graders (Glewwe et al., 2016). Ma et al. (2014) found that providing children at 252 primary schools with free glasses increased test scores by 0.11 standard deviations compared to students in the control group.

Although significant effects of improving access to eyeglasses were found in these studies, two major limitations exist. First, in addition to the prevalent unaddressed myopic problem, low-SES areas often face other problems that are tied to educational outcomes in a condition of budget constraints, such as teacher shortages (Tran & Smith, 2021). Such constraints may lead to the financial investment in offering eyeglasses at scale to compete with other necessary educational supplies, causing a decrease in its priority. Second, even if eyeglasses are provided completely or partially by the public sector, students' actual take-ups may not be guaranteed, as found to be approximately 53.11% for overall take-up rate according to a meta-analysis (Wu et al., 2023). For example, in a study by Glewwe et al. (2016) on the Gansu Vision Intervention Project (GVIP), one-third of the free glasses offered to low-income primary schools were turned down, even though a large positive effect on test scores was found. In Oaxaca, Mexico, 34% of students aged 5 to 18 who were provided with free eyeglasses reported that they did not wear them Holguin et al. (2006). Moreover, Ma et al. (2014) found low compliance and an insignificant effect if free glasses were offered in the form of a voucher, with a standard deviation of 0.07 lower in test scores than providing eyeglasses in class.

[1] Cited from an official press conference held by Ministry of Education of China in 2021 (see here).

3. Methodology

3.1. Research setting

This information intervention was conducted in Yun County, a low-income county in Yunnan, China, previously designated as one of the nation's poorest counties.[2] This county is also home to a sizable population of the Yi ethnic minority. The research sample used in this study represents a population characterized by relatively disadvantaged socio-economic status, making it suitable for studying relevant issues about students from impoverished and ethnic minority regions.

The research was carried out across all of the 20 middle schools in Yun County, involving 8262 participants comprising 7th and 8th graders who participated in the experiment. The experiment was conducted at the digital classrooms that are equipped with computers from every school in our sample. Every experiment was set to last for within 40 min. The head teachers of every class acted as the experimenters and took the charge of the lab-in-the-field experiments. To prevent spillover through communication among students during the experiment, they were seated with one empty seat between them. Additionally, all students were instructed to remain silent and were monitored by the head teacher throughout the experiment.

The experiment includes three sections: baseline information, information intervention, and post-intervention questions. To alleviate the experimenter demand effect, we concealed the actual experimental objectives by incorporating topics on mathematics and English learning into the three sections, making it less likely that students would realize the survey aimed to nudge them to wear glasses when needed.[3]

In the Section 1, we collected the baseline information, including students' myopia status, personal characteristics, beliefs related to myopia and eyeglasses, and their views on study-related issues (all listed in Table 2). The survey on myopia status included three self-reported questions:

1. Are you diagnosed as myopia? (followed by "yes" or "no")
2. Do you often find it hard to see the blackboard clearly in the class? (followed by "yes" or "no")
3. Do you wear eyeglasses? (followed by "yes" or "no")

It is worth mentioning that health examinations on all sample students' eyesight were conducted by local hospitals in October 2021, prior to the experiment, providing information about the students' myopia status. Based on these examinations, all students in our sample were aware of their myopia diagnosis. However, for those who were not diagnosed with myopia in October 2021, they may have developed myopia by March 2022, when the experiment began. Therefore, the students were asked about the Question 2 to determine whether they developed myopia after the health examinations. We defined those who answered "yes" to either the first or second question as having myopia.

For student characteristics, we collected information about their gender, race (Han or minority), and family's economic background. The survey recorded parental cellphone ownership as one household–background item, while the main descriptive tables and regression controls below use urban hukou as the preferred household economic-status proxy, for the reasons described in Section 3.3. Additionally, the survey elicited students' baseline beliefs about myopia and glasses-wearing in three aspects: first, whether wearing glasses benefits their academic performance; second, the estimation of the number of myopic students in the respondent's grade; and third, the perceived price

[2] The county's per capita GDP in 2021 was 37,055 CNY, showing not only a disparity compared to Yunnan Province's per capita GDP of 57,686 CNY but also a notable deviation from the national average of 80,976 CNY.

[3] The topics on mathematics and English learning exist in baseline information, information interventions and post-intervention questions, serving as the distraction from the actual experimental objectives.

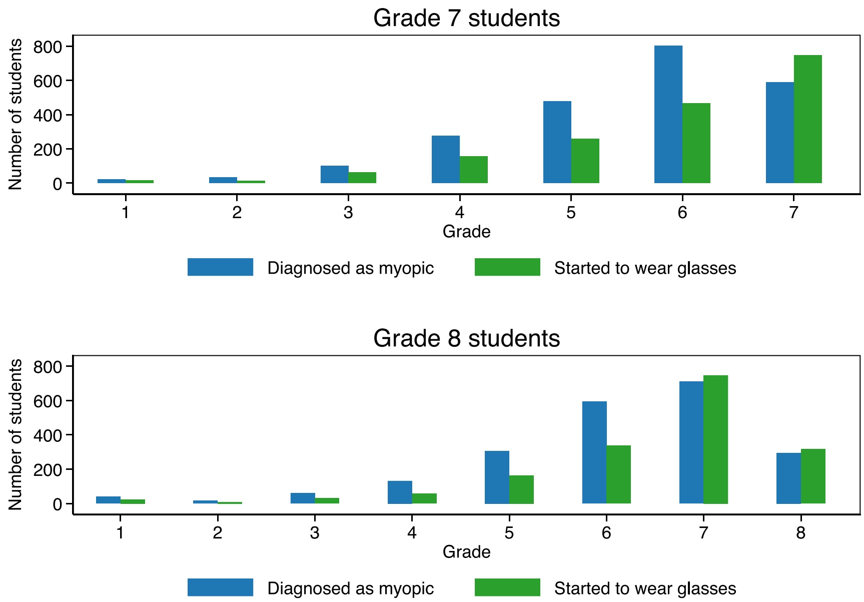

Fig. 1. Time gaps between becoming myopic and wearing eyeglasses.
Notes: The 8th grade's decline was attributed to the timing of the experiment that was conducted at the beginning of the second semester.

of a pair of standard eyeglasses. The first question was answered with "yes" or "no", while the remaining two with a number. Furthermore, students' study-related factors include their willingness to attend high school and their test scores from a county-wide unified examination that was administrative data provided by the county's education bureau.

We also collected data on when students first developed myopia and began wearing glasses. Fig. 1 shows the grade at which students were first diagnosed with myopia and started wearing glasses. It reveals that the peak incidence of myopia and the initiation of glasses-wearing occur in the 7th grade, suggesting that this is an opportune time to provide information nudges to 7th and 8th graders to encourage glasses use. Many students became myopic before the 7th grade (particularly during grades 5–6) but did not start wearing glasses promptly. The sharp decline for the grade 8 can be attributed to the timing of our survey, which was conducted at the beginning of the second semester.

3.2. Information intervention

After answering the pre-intervention questions, the information interventions, which were the highlight of the experiment, were randomly assigned to students within the digital classroom. One of five types of information was randomly displayed on each student's computer screen, with each student receiving only one type. The information was derived from research findings and facts about myopia and glasses-wearing.

The first information was about the short-term impacts of wearing glasses on academic achievement based on several research findings. Gomes-Neto et al. (1997) found that the poor vision of students in rural Northeast Brazil was associated with low school performance, including the high probability of dropping out and low probability of matriculation. Hannum and Zhang (2012) found that wearing glasses increased the math and literacy test scores of Chinese middle school students by 0.27 and 0.43 standard deviations, respectively. However, students may not have a complete understanding of the benefits of wearing glasses for their academic performance after developing myopia. To examine this factor, the following information was provided: "Myopia can hinder you from seeing the blackboard clearly and keeping up with lectures, leading to a decline in academic performance".

The second information was about the long-term consequences of uncorrected myopia for eye health and future opportunities. Unaddressed myopia can result in severe visual impairment, including glaucoma, macular degeneration, retinal detachment, and blindness (Verhoeven et al., 2015; World Health Organization, 2019). Moreover, myopia negatively affects economic productivity. In a meta-analysis, Naidoo et al. (2019) estimated that the global productivity loss resulting from uncorrected myopia was approximately 24 billion USD in 2015. Boudreaux and Lipton (2021) found that Medicaid adult vision coverage in the U.S. that offered vision screening and eyeglasses to low-income parents of dependent children significantly improved their labor market activities. However, students who are experiencing vision problems may not see the need for glasses in the future, especially if they have adjusted to their current visual state without glasses. To test this factor, this study provided the following information: "Wearing glasses in time can significantly prevent eyes from worsened myopia. If you experience myopia, not wearing glasses will lead to the continued deterioration of your vision, which will eventually impact your labor market opportunities". Because this message did not enumerate specific occupations or income ranges, we interpret T2 as a future-consequences salience treatment rather than as precise information about labor-market returns.

Third, this study provides national statistics on the percentage of students having myopia in China. Students could underestimate the prevalence of myopia among their peers because myopia is not visible if one does not wear glasses. This underestimation could prompt students who are concerned about their social identity to avoid wearing glasses after developing myopia. And the social pressure related to glasses-wearing can be substantial. World Health Organization (2019) reported that some people regard wearing eyeglasses as a disability. Odedra et al. (2008) found that some Tanzanian students refused to wear eyeglasses because they feared ridicule. A similar reason was noted by Gogate et al. (2013) who found that a common reason among Indian students for refusing eyeglasses was the "fear of being teased by other children". Thus, offering the information about myopia prevalence may help students to have a better understanding of the disease's ubiquity. The information we provided was: "Myopia is a very common problem in our country. The nationwide proportion of middle school students who experience myopia is 74%. There is no reason to feel ashamed about wearing glasses after developing myopia; doing so is a sensible response to a common health condition".

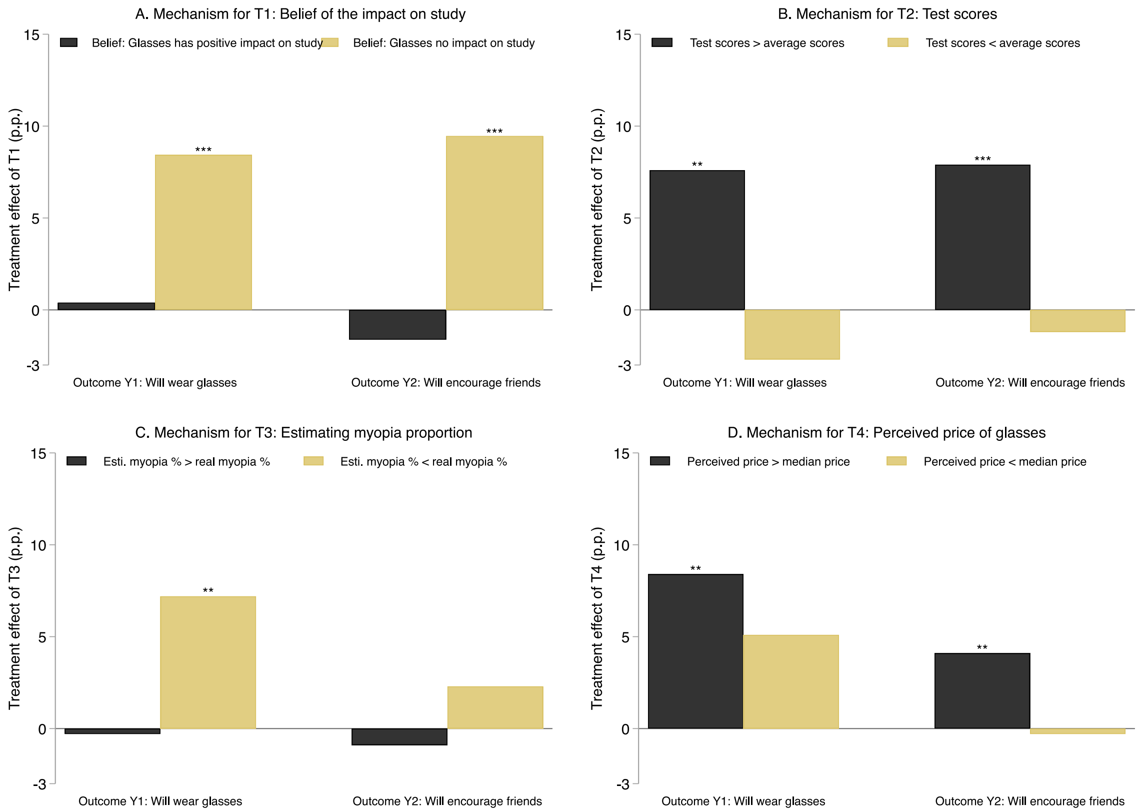

Fig. 2. Behavioral mechanism: comparing the nudge effects across subgroups.
Notes: (1) To examine the behavioral mechanisms behind the nudge effects from four types of intervention information, each of the four graphs compares a specific nudge effect between two subgroups. (2) ***, **, and * indicate the statistical significance of the nudge effect at the 1, 5, and 10 percent critical level based on robust standard errors clustered by school-class.

Fourth, students may not wear glasses because they overestimate eyeglasses prices. Although research regarding this factor is scant, Glewwe et al. (2016) found that parents' perceived cost of glasses was negatively associated with purchasing glasses for their children. Additional research has found a negative relationship between the perceived cost of other educational investments, such as college tuition, and education decisions (Dynarski et al., 2022; Linos et al., 2021). This suggests that students' perceived cost of eyeglasses as an investment in their education might influence their decision-making. To examine the effects of information about the price of eyeglasses, this study provides the following: "The average online price of a pair of glasses ranges from RMB 200 to RMB 500, way cheaper than the offline prices, which is thanks to economic development. Research shows that buying a pair of eyeglasses is a good investment for students who have myopia".

To estimate the causal effects of these four types of information, students were also randomly assigned to a control group that did not receive any information. Instead, the words displayed on the control group's computer screens were: "Have a 30-second rest and please click to continue". This control group created a scenario in which students made decisions without any intervention.

The grouping overview is as follows:

- **Control:** "Have a 30-second rest and please click to continue".
- **T1 (short-term impact):** "Myopia can hinder you from seeing the blackboard clearly and keeping up with lectures, leading to a decline in academic performance".
- **T2 (long-term impact):** "Wearing glasses in time can significantly prevent eyes from worsened myopia. If you experience myopia, not wearing glasses will lead to the continued deterioration of your vision, which will eventually impact your labor market opportunities".
- **T3 (nationwide prevalence of myopia):** "Myopia is a very common problem in our country. The nationwide proportion of middle school students who experience myopia is 74%. There is no reason to feel ashamed about wearing glasses after developing myopia; doing so is a sensible response to a common health condition".
- **T4 (price of a pair of glasses):** "The average online price of a pair of glasses ranges from RMB 200 to RMB 500, way cheaper than offline prices, which is thanks to economic development. Research shows that buying a pair of eyeglasses is a good investment for students who have myopia".

The informational treatments discussed above were displayed for one minute before automatically transitioning to the post-intervention questions, during which students in all five groups could not operate the computers. In the post-question section, students were asked two questions as the outcomes of interest in our study:

- **Outcome 1 (students who wore glasses skipped the question):** "Will you wear eyeglasses after you develop myopia?" (followed by "yes" or "no")
- **Outcome 2 (all students would answer):** "Will you encourage myopic friends to wear glasses?" (followed by "yes" or "no")

Overall, the overview of the RCT design is illustrated in Table 1.

3.3. Balance test and descriptive statistics

Table 2 reports the balance check of our grouping randomization. We conducted 52 t-tests to compare each treatment group with the control group for each observed variable, as well as a multinomial logistic regression of the treatment assignment (ranging from 0 to

Table 1
Experimental design.

October, 2021	Health examinations for students on their myopia status
March, 2022	**Survey experiment with a county random sample of 7th and 8th grade students**
	Collecting students' baseline information
Control	No information *(N=1651)*
Treatment 1	Short-term impact *(N=1648)*
Treatment 2	Long-term impact *(N=1644)*
Treatment 3	Nationwide % myopic *(N=1653)*
Treatment 4	Eyeglasses price *(N=1666)*
Outcome 1	Will wear glasses after developing myopia? (Students who wore glasses skipped the question)
Outcome 2	Will encourage myopic friends to wear glasses ? (All students answered the question)

Notes: This table shows the experimental design of eyeglass information intervention in 2022. Randomization was independently conducted at the student level.

4, with 0 standing for the control group) on the observed variables. Out of the total 52 t-tests, 46 tests showed no statistically significant differences. Additionally, the joint F test *p*-value from a multinomial logistic regression is 0.3019, indicating that the observed students' characteristics cannot predict the treatment assignment.

Table 3 presents the descriptive statistics for the full sample, as well as three subsamples: myopic students who did not wear glasses, myopic students who already wore glasses, and non-myopic students. Panel A shows the information about students' myopia status, including the diagnosis of myopia, glasses-wearing, and the duration of myopia. The overall myopia rate is 68.4% among all students, while 60.5% of the myopic students wore glasses. These two figures are comparable to the national averages of 71.1% for the myopia rate and 62.3% for the glasses-wearing rate among myopic students.[4]

Students' personal characteristics are shown in panel B, including gender, ethnicity, age, and household economic status. Our sample is gender-balanced with female students accounting for 50.1%, while more girls who were myopic wore glasses. The ethnicity shows that minority students are the majority of our sample, consistent with the population feature we mentioned in Section 3.1. Students' average age is 14, same for the three subgroups. To measure students' household economic status, we use the type of hukou from the students as the proxy.[5] In the context of this research, students are assigned to middle schools according to their location of hukou, those with urban hukou attending middle schools in the urban region while those with rural hukou attending middle schools in the rural region. We categorize students in our dataset into these two types of hukou based on the location of the middle schools they attended. Therefore, students with urban hukou are considered to have a better economic background than those with rural hukou. As shown in Table 3, the proportion of having urban hukou among students who were myopic and wore glasses is 48.2%, above the full-sample average, while the proportion among those who were myopic but did not wear glasses is 27.4%, the lowest among the three subgroups. This pattern is consistent with the findings from literature that myopic students from better economic background are more likely to wear glasses (Glewwe et al., 2016; Wu et al., 2023). It also validates the use of hukou as an indicator of family economic background hereafter.

Panel C exhibits the vision- and glasses-related beliefs among students, including the impact of glasses-wearing on the study, estimated prevalence of myopia among the peers, and the perceived price of glasses. The first belief was measured by asking students whether wearing glasses could benefit their academic performance if they were myopic. It is shown that the majority of students did not believe that wearing glasses positively affects their studies. Somehow, the proportion for those who wore glasses was even lower than the average level of the full sample, probably because they did not find significant progress in their studies after wearing glasses. The overall low level of this belief suggests that the benefit of glasses-wearing was underestimated among the students.

[4] These two figures for the national average are cited from an official press conference (see here).

[5] Hukou is a household registration system in China and every citizen is registered with a hukou based on the residential location. The location of a person's hukou determines their access to social services including health/medical services as well as a student's access to education. The two types of hukou are urban and rural, which are determined by whether the person's family resides in an urban or rural region. Given that social services from urban regions are superior to those from rural regions, families with higher SES prefer to move to urban region and attain urban hukou. Therefore, it is generally considered that families with urban hukou have a better economic background than those with rural hukou.

Table 2
Balance checks.

	(1) Control	(2) T1	(3) T2	(4) T3	(5) T4	Diff (1)–(2)	Diff (1)–(3)	Diff (1)–(4)	Diff (1)–(5)
Panel A. Myopia status									
Diagnosed as myopia (=1)	0.675	0.686	0.679	0.683	0.695	−0.011	−0.003	−0.008	−0.020
	[0.022]	[0.023]	[0.023]	[0.024]	[0.024]				
Wear glasses (=1)	0.411	0.419	0.413	0.405	0.422	−0.009	−0.002	0.006	−0.011
	[0.030]	[0.027]	[0.031]	[0.026]	[0.031]				
Myopia duration (yrs)	1.426	1.422	1.485	1.402	1.459	0.004	−0.059	0.024	−0.033
	[0.081]	[0.082]	[0.087]	[0.106]	[0.060]				
Panel B. Characteristics									
Female (=1)	0.494	0.498	0.511	0.483	0.517	−0.004	−0.017	0.011	−0.023
	[0.017]	[0.014]	[0.016]	[0.017]	[0.017]				
Minority race (=1)	0.591	0.599	0.603	0.598	0.627	−0.008	−0.012	−0.007	−0.035**
	[0.035]	[0.035]	[0.034]	[0.037]	[0.033]				
Age	14.274	14.298	14.285	14.287	14.291	−0.024	−0.012	−0.013	−0.017
	[0.106]	[0.100]	[0.109]	[0.105]	[0.108]				
Urban *hukou*	0.377	0.389	0.360	0.336	0.367	−0.012	0.017	0.042	0.010
	[0.116]	[0.116]	[0.114]	[0.113]	[0.114]				
Panel C. Beliefs									
Positive effects on study (=1)	0.315	0.339	0.339	0.339	0.337	−0.024	−0.024	−0.024	−0.022
	[0.016]	[0.018]	[0.016]	[0.015]	[0.015]				
Estimated myopia prevalence	51.815	52.854	52.103	52.140	52.348	−1.040	−0.288	−0.326	−0.533
	[1.970]	[1.986]	[1.746]	[1.775]	[1.964]				
Perceived price of glasses (RMB)	1715.448	1696.329	1664.825	1685.282	1640.460	19.120	50.623	30.167	74.989*
	[35.832]	[42.907]	[40.578]	[28.060]	[30.563]				
Panel D. Study-related factors									
Want to attend high school (=1)	0.807	0.823	0.832	0.805	0.822	−0.016	−0.025	0.002	−0.014
	[0.021]	[0.022]	[0.020]	[0.020]	[0.017]				
Chinese test score (raw, 0–100)	65.697	66.551	65.869	65.012	66.304	−0.854*	−0.173	0.685	−0.607
	[1.715]	[1.677]	[1.604]	[1.510]	[1.575]				
English test score (raw, 0–100)	52.059	53.318	51.450	50.895	52.993	−1.259*	0.609	1.164	−0.934
	[3.964]	[4.143]	[3.827]	[3.621]	[3.798]				
Math test score (raw, 0–100)	54.080	55.257	53.227	52.146	54.695	−1.177	0.853	1.934*	−0.615
	[3.728]	[3.741]	[3.382]	[3.268]	[3.495]				
Observations	1651	1648	1644	1653	1666				

Notes: (1) The table reports the mean and standard deviation (in square brackets) of each variable. (2) The columns after column (5) report the control-treatment differences. ***, **, and * indicate the significance of the differences at the 1, 5, and 10 percent critical level based on robust standard errors clustered by school-class. (3) The joint F test p-value from a multinomial logit model using all the covariates and school-class fixed effects to predict treatment assignment status is 0.3019.

The second belief was measured by asking students' estimations of the myopia rate in the grade. It would show the underestimation of myopia prevalence had it been dramatically lower than the reality. Comparing the estimated rate across the four columns, they are consistently lower than the real average myopia rate of 68.4%.

The third belief was measured by asking students' perceived price of a pair of standard eyeglasses. It shows that eyeglasses price was greatly overestimated, given that the online price for a pair of standard glasses is approximately RMB 200–500 (or USD 28 to USD 69) in China.

At last, panel D reports the study-related factors including their aspiration to attend high school and their test scores (administrative data). It is shown that students who wore glasses tend to be the high-achievers who wanted to attend high schools in the future.

Comparing the three beliefs between myopic students who did not wear glasses and those who already wore glasses, the former ones obviously held biased beliefs which might be the barriers preventing them from wearing glasses. Taken together, students who wore glasses generally belonged to relatively affluent families, held less biased beliefs regarding vision and glasses-wearing, and were more likely to achieve high academic performance.

A notable asymmetry is also worth highlighting before we turn to the experimental results. As shown by the control means in Table 5, myopic students without glasses report the lowest willingness to wear glasses themselves (44.9%), but a substantially higher willingness to encourage myopic friends to wear glasses (60.8%). In other words, this group is the most reluctant to personally adopt the technology, but is more willing to recommend it to peers. This pattern is consistent with the existence of a private social cost (e.g., fear of teasing or appearance anxiety) that binds tightly when one personally wears glasses but weakens when the choice is borne by someone else. It also suggests that for this subgroup, abstract endorsement of glasses-wearing as a norm is not the binding constraint; rather, the constraint sits on the personal-adoption margin.

3.4. Empirical strategy

To estimate the causal effects of the information nudges, we employ a linear regression model. Our analysis distinguishes between two mechanisms: the update of private beliefs (captured by the decision to wear glasses) and the shift in social norms (captured by the willingness to encourage peers). We hypothesize that if an intervention successfully reduces the stigma associated with glasses, it will increase the likelihood of students advocating for the technology among their peers.

We estimate the average treatment effects of receiving information nudges using the following linear regression:

$$Y_{i,s,c} = \beta_0 + \sum_{n=1}^{4} \beta_n Nudge_i^n + \gamma X_i + \varphi_{s,c} + \varepsilon_{i,s,c} \tag{1}$$

where $Y_{i,s,c}$ is the outcome of interest for a student i at school s and class c. As noted above, we utilize two dependent variables for Y: (1) Private Adoption (Will you wear glasses?), and (2) Public Endorsement (Will you encourage friends?). $Nudge^n$ is a dummy variable for the student i receiving one of four types of information nudges, where n is the specific type of information a student receives. Because randomization was conducted at the individual level within digital classrooms and we estimate intention-to-treat (ITT) effects, β_n identifies the causal effect of being assigned to nudge group n on the stated outcome of interest. X_i is a vector of pre-intervention controls that includes the personal characteristics summarized in Panel B of Table 2 (gender, ethnicity, age, and urban hukou), the baseline beliefs about glasses and myopia

Table 3
Descriptive statistics.

	(1) Full sample	(2) Myopic w/o glasses	(3) Myopic w/ glasses	(4) Not myopic
Panel A. Myopia status				
Diagnosed as myopia (=1)	0.684	1	1	0
	(0.465)	(0)	(0)	(0)
Wear glasses (=1)	0.414	0	1	0
	(0.493)	(0)	(0)	(0)
Myopia duration (yrs)	1.439	0.962	1.751	.
	(1.404)	(1.277)	(1.393)	(.)
Panel B. Characteristics				
Female	0.501	0.472	0.621	0.367
	(0.500)	(0.499)	(0.485)	(0.482)
Minority race	0.604	0.630	0.597	0.590
	(0.489)	(0.483)	(0.491)	(0.492)
Age	14.29	14.30	14.29	14.27
	(0.715)	(0.721)	(0.711)	(0.715)
Urban *hukou*	0.366	0.274	0.482	0.292
	(0.482)	(0.446)	(0.500)	(0.455)
Panel C. Beliefs				
Positive effects on study	0.334	0.301	0.324	0.374
	(0.472)	(0.459)	(0.468)	(0.484)
Estimated myopia prevalence	52.25	51.27	57.84	45.78
	(22.96)	(22.77)	(21.63)	(22.99)
Perceived glasses price (RMB)	1680.4	1778.2	1561.1	1753.1
	(1054.0)	(1122.7)	(855.6)	(1203.4)
Panel D. Study-related factors				
Want to attend high school (=1)	0.818	0.777	0.883	0.768
	(0.386)	(0.416)	(0.322)	(0.422)
Average test scores (raw, 0–100)	57.33	54.24	64.10	51.07
	(20.10)	(19.05)	(19.87)	(18.55)
Observations	8262	2229	3420	2613

Notes: (1) Standard deviations are reported in parentheses. (2) "Positive effects on study" refers to those who initially believed that wearing glasses after developing myopia has a positive effect on study; "Estimated myopia prevalence" refers to the question about the estimated proportion of myopic students in the grade; "Perceived glasses price (RMB)" refers to the question about the perceived price of a pair of glasses. (3) Test scores in Panel D are the raw percentage scores (0–100) from the county-wide unified examination. These should not be confused with the standardized (mean-zero, unit-variance, within-school) scores used as outcomes in Section 5; the standardized form is used only in the regressions in Table 8.

summarized in Panel C (beliefs about the impact of glasses on study, the estimated myopia prevalence among peers—which we use as the proxy for stigma-related concerns—and the perceived glasses price), and the baseline test scores summarized in Panel D. The leave-one-out prevalence of glasses-wearing among classmates is not included in X_i; it enters the peer heterogeneity analysis in Table 7. $\varphi_{s,c}$ is a vector of school-class fixed effects. $\varepsilon_{i,s,c}$ is an error term, clustered by school-class. We note that because students are assigned to middle schools based on the urban/rural location of their hukou, much of the cross-sectional variation in hukou is absorbed by $\varphi_{s,c}$; we nonetheless retain hukou as an explicit control to capture residual within-school variation.

4. Results

4.1. Average treatment effects

Table 4 reports the baseline results of nudge effects for two outcome variables: the stated willingness to wear glasses after developing myopia (columns 1–3) and the stated willingness to encourage friends to wear glasses after they develop myopia (columns 4–6). After controlling for covariates and including school-class fixed effects (columns 3 and 6), T1 and T3 are statistically significant for the first outcome, while T1 and T2 are statistically significant for the second outcome.

Specifically, students who were non-myopic or myopic without glasses were 5.6 percentage points more likely to wear glasses after they were nudged by T1 (col. 3), which is equivalent to a 9.3% increase from the control group's mean. For those nudged by T3, they were 5.2 percentage points more likely to wear glasses, equivalent to an 8.6% increase from the control mean. Regarding the second outcome variable for all participants, T1 and T2 increased the likelihood of encouraging myopic friends to wear glasses by 5.8 percentage points and 4.5 percentage points, which is equivalent to an 8.3% and a 6.4% increase from the control mean, respectively. After adjusting p-values for multiple hypothesis testing, these nudge effects remain statistically significant.[6] In addition, p-values indicate that T1's estimates are significantly different from that of T2 for the first outcome, and from those of T3 and T4 for the second outcome. Overall, information about the short-term benefits of wearing glasses (T1) was consistently the most effective, as indicated by the effect size and statistical significance across the two outcome variables.

However, myopic students without glasses may be the group of greatest interest, as they most need to be nudged to wear glasses. To examine this and compare nudge effects across subgroups, Table 5 divides the baseline sample into three subgroups: myopic students who did not wear glasses, non-myopic students, and myopic students who already wore glasses.

Table 5 shows that the control means of myopic students without glasses (44.9% and 60.8%) were the lowest among the three subgroups. The first control mean (44.9%) suggests that, without any intervention, more than half of the myopic students without glasses would continue not wearing glasses. In contrast, non-myopic students were more willing to wear glasses if they developed myopia and to encourage friends to wear glasses. This disparity in willingness between the two groups does not appear to be explained by household economic status alone: as shown in Table 3, the difference in urban hukou between these two groups is small. Thus, we assume that this may be attributed to the

[6] We use Michael Anderson's code to compute sharpened False Discovery Rate (FDR) q-values, which is based on the theory from Thomas (1994).

Table 4
Baseline results of nudge effects on two outcome variables.

Sample	Myopic w/o glasses + Non-myopic			All participants		
Outcomes	Will wear glasses if myopic			Will encourage myopic friends		
	(1)	(2)	(3)	(4)	(5)	(6)
Control mean	0.598	0.604	0.604	0.702	0.701	0.701
T1 (short-term)	0.066***	0.057***	0.056**	0.055***	0.056***	0.058***
	(0.019)	(0.021)	(0.023)	(0.016)	(0.015)	(0.016)
T2 (long-term)	0.022	0.024	0.022	0.043**	0.048***	0.045***
	(0.024)	(0.025)	(0.026)	(0.017)	(0.016)	(0.016)
T3 (prevalence)	0.045**	0.047**	0.052**	0.016	0.019	0.019
	(0.020)	(0.023)	(0.026)	(0.014)	(0.015)	(0.015)
T4 (price)	0.046**	0.043*	0.043	0.014	0.012	0.017
	(0.022)	(0.024)	(0.026)	(0.015)	(0.016)	(0.016)
Q-value (T1)	0.007	0.028	0.036	0.007	0.007	0.007
Q-value (T2)	0.202	0.199	0.205	0.036	0.017	0.028
Q-value (T3)	0.051	0.062	0.062	0.173	0.166	0.166
Q-value (T4)	0.060	0.095	0.102	0.202	0.205	0.188
P-value {T1 = T2}	0.011	0.051	0.040	0.400	0.628	0.408
P-value {T1 = T3}	0.322	0.665	0.864	0.006	0.016	0.010
P-value {T1 = T4}	0.314	0.507	0.535	0.016	0.018	0.026
Observations	4842	4433	4432	8262	7577	7575
R-squared	0.002	0.126	0.175	0.002	0.035	0.084
Covariates	No	Yes	Yes	No	Yes	Yes
School-class FE	No	No	Yes	No	No	Yes

Notes: (1) Covariates include all the pre-intervention variables summarized in Table 3. (2) Q-values are the False Discovery Rate (FDR) adjusted p-values, reported as the results of multiple hypothesis testing. (3) Robust standard errors clustered by school-class are reported in parentheses; ***, **, and * reflect unadjusted p-values, indicating significance at the 1, 5, and 10 percent critical level. (4) "Control group mean" stands for the average outcome of control group. (5) P-values indicate the significance of estimate difference between information interventions. (6) After including control variables, a small percentage of observations are dropped from the regression due to missing data in those specific control variables.

Table 5
Subsample analysis for baseline results.

Outcomes	Will wear glasses if myopic		Will encourage myopic friends		
Sample	Myopic w/o glasses (1)	Not myopic (2)	Myopic w/o glasses (3)	Not myopic (4)	Myopic w/ glasses (5)
Control mean	0.449	0.731	0.608	0.741	0.729
T1 (short-term)	0.070*	0.036	0.070*	0.023	0.061**
	(0.041)	(0.027)	(0.038)	(0.024)	(0.023)
T2 (long-term)	0.013	0.019	0.045	0.010	0.065***
	(0.037)	(0.025)	(0.036)	(0.026)	(0.021)
T3 (prevalence)	0.037	0.058*	0.020	0.005	0.026
	(0.035)	(0.033)	(0.035)	(0.024)	(0.021)
T4 (price)	0.069**	0.005	0.059	−0.011	0.009
	(0.034)	(0.031)	(0.040)	(0.029)	(0.024)
Q-value (T1)	0.217	0.486	0.210	0.655	0.061
Q-value (T2)	0.755	0.755	0.486	0.755	0.047
Q-value (T3)	0.618	0.220	0.755	0.786	0.486
Q-value (T4)	0.098	0.786	0.486	0.755	0.755
P-value {T1 = T2}	0.103	0.482	0.524	0.654	0.870
P-value {T1 = T3}	0.496	0.301	0.202	0.464	0.154
P-value {T1 = T4}	0.984	0.174	0.799	0.274	0.036
P-value {T2 = T3}	0.535	0.219	0.533	0.835	0.058
P-value {T2 = T4}	0.107	0.624	0.745	0.530	0.012
P-value {T3 = T4}	0.375	0.040	0.360	0.542	0.406
Observations	2045	2385	2045	2385	3142
R-squared	0.167	0.153	0.168	0.121	0.112
Covariates	Yes	Yes	Yes	Yes	Yes
School-class FE	Yes	Yes	Yes	Yes	Yes

Notes: (1) Robust standard errors clustered by school-class are reported in parentheses; ***, **, and * reflect unadjusted p-values, indicating significance at the 1, 5, and 10 percent critical level. (2) P-values indicate the significance of estimate difference between information interventions.

first-hand experience of myopia: non-myopic students may not fully understand the inconveniences associated with myopia and the benefits of wearing glasses. They may perceive wearing glasses as a hypothetical necessity if they were to develop myopia in the future. On the other hand, myopic students who were already experiencing vision problems may not see the need for glasses in the future, especially if they had adjusted to their current visual state without them.

The results of Table 5 contrast greatly with the baseline results. After controlling covariates, incorporating school-class fixed effects, and adjusting p-values for multiple hypothesis testing, T1 and T4 affected myopic students without glasses significantly (col. 1). Information about short-term benefits (T1) and information about eyeglasses price (T4) improved their willingness to wear glasses by 7.0 pp and 6.9 pp, respectively, both roughly equivalent to a 15% increase from the control mean. Furthermore, information about the short-term impacts (T1) and long-term impacts (T2) improved the willingness to encourage friends among myopic students wearing glasses by 6.1 pp (an 8.4% increase from the control mean) and 6.5 pp (an 8.9% increase from the control mean).

The above results suggest that unawareness of the short-term benefits of wearing glasses and the cost of purchasing them may be the primary barriers to wearing glasses after developing myopia. In addition, we also find that the information about short- (T1) and long-term impacts (T2) had significant effects on the willingness of myopic students who already wore glasses to encourage their friends, whereas non-myopic students were basically immune to the four types of information. The concentration of T2's effect among myopic students who already wore glasses is itself informative. These students have first-hand experience with the daily costs and benefits of glasses, including any social cost. The long-term-impact message—which emphasizes how unaddressed myopia can degrade longer-run eye health and future opportunities—supplies a goal-aligned rationale that they can credibly transmit to peers, because they themselves have already paid the up-front adoption cost. In contrast, for myopic students without glasses, the social cost of personally wearing glasses is still binding, so long-term-impact information alone is not sufficient to change their private-adoption choice. The pattern is therefore consistent with our broader interpretation that T2 operates primarily through salience and goal-alignment rather than through removing the private social cost of adoption.

At last, the results above could also shed light on the experiment demand effect (EDE). We have mentioned that the survey elicited students' willingness for two behavior right after the information nudge. If the EDE is present, we would expect to observe consistent nudge effects among the four treatments and approximate control means in both outcome variables. However, the results in Table 5 show disparate patterns of nudge effects and control means from the two outcomes. Combined with the precautionary measures mentioned in Section 3.1, the limited threat posed by the EDE could be established. Furthermore, we also conducted a robustness check in Appendix B, using students' intention to attend high school as a placebo test for the EDE. The results in Table B1 confirm that the observed nudge effects were not driven by the EDE.

4.2. Mechanism analysis

So far we cannot figure out why the four types of information have such disparate effects on different subgroups. Thus, we turn to the question of what is the behavioral mechanism by which the information nudge works to affect students' willingness.

It is widely accepted that information intervention mainly functions as the provision of new information, by which it updates subjects' belief. However, recent studies find that information intervention may also work through increasing the salience of the information subjects already know, apart from providing new information (Bettinger et al., 2021; Ma et al., 2023). Bettinger et al. (2021) suggest that if information are made salient, agents might undertake actions pertaining to that information to a greater extent, regardless of their initial beliefs about returns. These suggest that the information about myopia and eyeglasses could also serve as a reminder and draw attention to the issues on myopia.

To rigorously distinguish between these two mechanisms, we employ a subgroup identification strategy based on students' baseline beliefs. We posit that:

1. **Belief Updating** is identified if the information nudge significantly affects students whose prior beliefs were misaligned with the treatment message (i.e., those who held incorrect beliefs). For these students, the intervention provides new information that corrects their priors.
2. **Salience (Augmentation)** is identified if the information nudge significantly affects students whose prior beliefs were already aligned with the treatment message (i.e., those who already knew the information). For these students, the intervention does not provide new facts but rather makes existing knowledge more salient or augments their focus on the issue.

Based on this framework, we examined T1 with the belief regarding the impact of wearing glasses on academic performance, T3 with the estimated myopia rate in the grade, and T4 with the perceived price of a pair of standard eyeglasses. It is worth noting that students' baseline belief related to T2 was not collected because it could be well replaced by students' test scores. An individual's commitment to long-term goals is difficult to measure, whereas test scores can reflect a student's willingness to pursue long-term goals. This is particularly true in a country like China, where academic performance is strongly associated with future development.

Fig. 2 illustrates how the nudge effects vary across subsamples divided by the baseline belief. Each subfigure exhibits the effect of the treatment arm of interest on two willingness. The detailed regression results including four treatment arms are displayed in Table A3 (mechanism for T1), Table A4 (mechanism for T2), Table A5 (mechanism for T3), and Table A6 (mechanism for T4), respectively.

In Fig. 2A, we divided the sample by whether the student believed that wearing glasses would have a positive impact on the study. We find that T1 significantly affected students who initially believed that wearing glasses had no impact on their studies. However, T1 had little effect on those who already believed in the impact of glasses-wearing. This pattern indicates that the information about the short-term benefits of glasses-wearing increased the willingness through updating the belief for those who initially believed that wearing glasses had no impact on their studies. This also sheds light on why the nudge effects of T1 were comparatively larger among myopic students with or without glasses in Table 5, because their baseline belief was lower than the average level (shown in Table 3).

In contrast to T1, T2 focuses on the long-term benefits of glasses-wearing. We presume that students who value long-term issues would spend more time learning for goals and interests in the long run. Therefore, high-achievers might be more interested in the information of T2. In Fig. 2B, we divided the sample by whether the student's average test score was higher than the school-grade average. The figure shows that T2 significantly improved both the willingness of those whose test scores were higher than the median of the population, while T2 barely affected the willingness of those whose test scores were lower than the median. In contrast to the T1, T2 worked through increasing the salience of the long-term benefits of wearing glasses for those who valued the long-term goals. This result helps explain the significant effect of T2 on myopic students who wore glasses in Table 5, because their average test scores were the highest among all students.

The information of T3 was about myopia prevalence, addressing concerns related to the discrimination against glasses-wearing. Students who underestimated the myopia prevalence among their peers might be more susceptible to the discrimination, which may result in low take-up of glasses among them. Thus, we divided the sample based on whether the student's baseline estimation of school-grade myopia proportion was higher than the real myopia proportion at the school-grade level (Fig. 2C). The result shows that T3 increased both types of willingness among those who underestimated the prevalence of myopia, with a substantially large effect on the first type of willingness. This supports our hypothesis and suggests that T3 worked through updating the belief about myopia prevalence. Based on this mechanism, it is plausible to

Table 6
Heterogeneity by myopia duration and academic performance among myopic students without glasses.

Outcome	Will wear glasses after myopia			
Sample	Myopia < 1yr (1)	Myopia > 1yr (2)	Test scores > Average (3)	Test scores < Average (4)
Control mean	0.464	0.435	0.442	0.459
Panel A. Specific nudge effect				
T1 (short-term)	0.128*	0.013	0.095*	0.015
	(0.071)	(0.043)	(0.054)	(0.051)
T2 (long-term)	0.050	0.003	0.068	−0.072
	(0.069)	(0.053)	(0.052)	(0.051)
T3 (prevalence)	0.108*	−0.012	0.090**	−0.032
	(0.058)	(0.044)	(0.040)	(0.058)
T4 (price)	0.167**	−0.005	0.063	0.055
	(0.065)	(0.056)	(0.053)	(0.047)
Observations	929	1100	1076	955
R-squared	0.253	0.222	0.212	0.208
Covariates & School-class FE	Yes	Yes	Yes	Yes
Panel B. Overall nudge effect				
Nudged	0.115**	0.003	0.078**	−0.005
	(0.053)	(0.036)	(0.037)	(0.036)
Observations	929	1100	1076	955
R-squared	0.249	0.221	0.212	0.202
Covariates & School-class FE	Yes	Yes	Yes	Yes

Notes: (1) The "Average" in columns 3 and 4 refers to average test scores at the school-grade level for every student we observe. (2) ***, **, and * indicate significance at the 1, 5, and 10 percent critical level based on robust standard errors clustered by school-class. (3) Coefficients significant at the 1% or 5% level remain significant after FDR adjustment.

see a comparatively larger effect of T3 on the willingness to wear glasses for non-myopic students in Table 5, because their estimated myopia rate was the lowest among all students.

T4 was designed to emphasize that glasses were more affordable online than offline. Compared with non-myopic and myopic students without glasses, myopic students wearing glasses should have more accurate information about the prices of glasses because they have bought one. However, the price distribution in Figure A1 shows that their perceived prices greatly exceeded the online price (RMB 200–500) provided in T4, even though their average perceived prices had been the lowest among the three kinds of student subgroups (see Table 3). This suggests that students from the remote and underdeveloped regions might be unfamiliar with the online price of glasses, due to the limited access to online shopping. Besides, given that the average perceived price of glasses-wearing students was RMB 1561 (or USD 216), it would, on average, took one parent's monthly income to buy a pair of glasses from an offline store.[7] In this case, without the information nudge, many students in our sample might not be unwilling to wear glasses when they develop myopia due to the high prices of glasses in offline stores.

To examine how the effect of T4 would vary with students' perceived glasses price, we divided the sample by whether the student's perceived price was higher than the school-grade median. Fig. 2D shows that T4 significantly increased the willingness for above-median subsample. Somehow, T4 also increased the first willingness for below-median subsample, probably because the average perceived price of students in below-median subsample was still higher than the informed online prices. Together, these findings indicate that T4 worked by updating beliefs about the actual costs of buying glasses. This also explains the significant effect of T4 on the willingness to wear glasses among myopic students without glasses, as their perceived prices of glasses were the highest among all students.

One caveat applies to this mechanism evidence. We did not use direct survey scales to measure sensitive traits such as appearance anxiety or long-term orientation. Asking about them before the nudges would have primed students and biased the treatment effects. Instead, we rely on proxies: the baseline belief about myopia prevalence stands in for stigma concerns, and baseline test scores for long-term orientation. Because these proxies are indirect, we treat the mechanism results as suggestive rather than definitive.

4.3. Heterogeneous effects

Having established the behavioral mechanisms, we now leverage heterogeneity analysis to serve two strategic functions: validating the presence of behavioral inertia and identifying the optimal targeting for policy design. We hypothesize that information gaps are not the only barrier; status quo bias and habituation may also dampen responsiveness. By examining how effects vary across subgroups, we can define the "window of opportunity" for intervention and move toward a precision education approach. We conducted subgroup analyses across three dimensions: (1) myopia duration, (2) academic performance, (3) peer group. Fig. 3 summarizes the subgroup analysis, and the detailed regression results are presented in Tables 6, and 7.

Myopia duration. Individuals with a long duration of myopia may have already adapted to their current visual state without glasses, and may not perceive the need for glasses in the future. This could pose a challenge in updating their beliefs and nudging them to wear glasses. To test this hypothesis, we divided the sample into students with myopia duration of within one year and beyond one year, and show the results in columns (1) and (2) of Table 6, respectively. Compared with those whose myopia duration were beyond one year, the effects of all four treatment arms were larger and more statistically significant for those with myopia duration within one year. To make easier comparison, we generate a new treatment variable named Nudged and use the following specification to measure the overall nudge effect:

$$Y_{i,s,c} = \beta_0 + \beta_1 Nudged_i + \gamma X_i + \varphi_{s,c} + \varepsilon_{i,s,c} \tag{2}$$

Compared with Eq. (1), we combine the four dummy variables representing the four corresponding treatment arms into a single dummy variable that indicates whether the student was treated or not. The new dummy variable, Nudged, measures the overall nudge effect. The remaining components of Eq. (1) remain unchanged in Eq. (2). The results for the overall nudge effect are presented in panel B. As expected,

[7] The local county-wide annual income was RMB 22502 per capita in 2022. See details here.

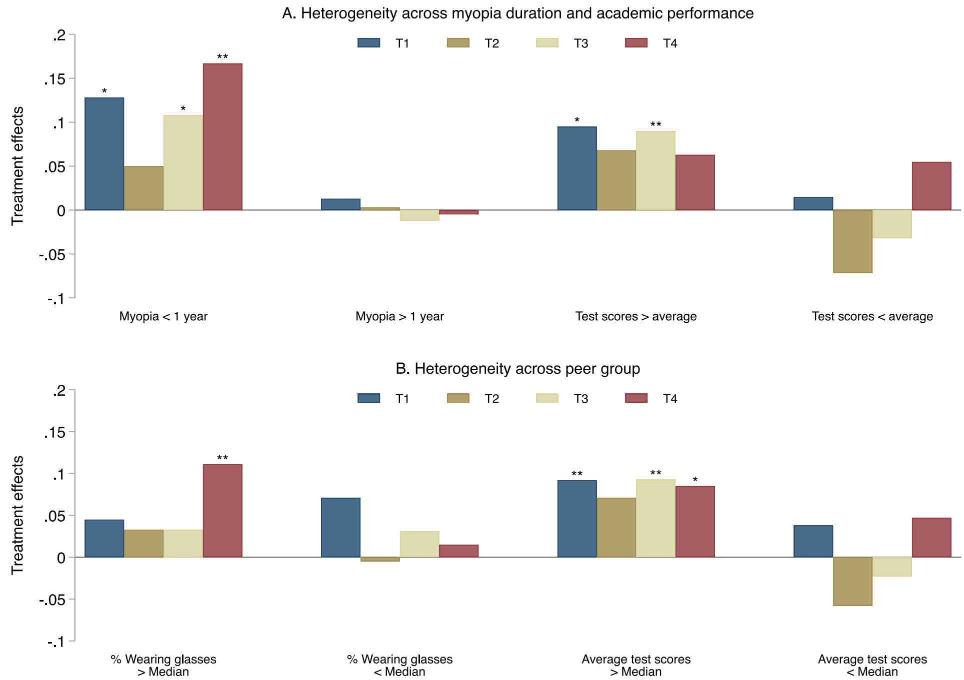

Fig. 3. Heterogeneous treatment effects across subgroups.
Notes: ***, **, and * indicate the statistical significance of the nudge effect at the 1, 5, and 10 percent critical level based on robust standard errors clustered by school-class.

the overall nudge effect was larger and more statistically significant for those with myopia duration less than one year, and remains robust after adjusting p-values. Together, these suggest that it is more effective to nudge those with relatively short duration of myopia to wear glasses.

Academic performance. We next test the complementarity hypothesis—that the utility of the nudge depends on the student's baseline valuation of academic success. Table 6 reports the heterogeneity in students' academic performance. We divide the students into two subgroups based on whether their average test scores were higher than the school-grade average. Unlike the sample in Table A4, here we confined the students to those who were myopic but did not wear glasses.[8] The first group consists of high-achieving students whose test scores were higher than the median (col. 3), while the second group consists of low-achieving students with test scores lower than the median (col. 4). Panel A shows that T1 and T3 had statistically significant effects on high-achieving students, while none of the four treatment arms had a significant effect on low-achieving students. Besides, high-achieving students were much more receptive to the T3 compared to low-achieving students, although it is statistically insignificant. Overall, high-achieving students were more effectively nudged than low-achieving ones, as also suggested by the overall nudge effects in Panel B. This pattern may be attributed to the fact that intervention information and education are complementary components (Duflo et al., 2015; Dupas & Miguel, 2017; Godlonton et al., 2016). High-achieving students are more likely to adopt beneficial information and adjust their behavior due to higher self-efficacy (Schwarzer, 1992; Schwarzer & Fuchs, 1996).

Two caveats apply to the discrete subgroups used above. The one-year cutoff for myopia duration and the school-grade-median split for test scores are practical choices rather than thresholds derived from medical or contextual evidence: the duration cutoff is intended to capture the behavioral distinction between newly diagnosed and visually adapted students, and the median split to separate higher- from lower-achieving students while keeping the two subsamples of comparable size. Because these cutoffs are not randomly assigned, the resulting contrasts should be read as descriptive comparisons across subsamples rather than as strict local average treatment effects. To confirm that our conclusions are not artifacts of where these cutoffs are placed, and to allow the nudge effect to vary smoothly and non-linearly with each moderator, we re-estimate both dimensions in Appendix C using continuous polynomial interactions—$Nudged$ interacted with a second-order polynomial in myopia duration and in the (standardized) test score. The polynomial specifications confirm the qualitative patterns reported here—an inverted-U effect on academic performance that peaks for around- and above-average achievers, and a nudge effect by duration that is concentrated among the recently diagnosed—while indicating that, for the highly concentrated duration distribution, the discrete contrast is the more stable summary. We therefore retain the discrete subgroup analysis in the main text and present the continuous and polynomial specifications as a robustness check in Appendix C.

Peer group. Finally, we explore whether nudge effects would vary systematically with one's peer group. Table 7 presents heterogeneity across two dimensions of peer groups: the proportion of classmates wearing glasses, and the average test scores of classmates.[9] Column (1) shows the results for those who have more classmates wearing glasses

[8] Fig. 2B and Table A4 use the broader mechanism sample of all students for whom the first outcome is defined (myopic students without glasses plus non-myopic students; $N \approx 4400$). In contrast, the academic-performance columns of Table 6 restrict to myopic students without glasses ($N \approx 2000$), and Table 7 additionally conditions on classmate composition. These sample differences explain why the estimates should not be read as inconsistent.

[9] To measure the proportion of classmates wearing glasses, we used the leave-one-out method and divided the number of one's classmates who wore glasses by the total number of students in the class, excluding the individual student being considered. The same method was applied to measure the average test scores of the student's classmates.

Table 7
Heterogeneity by peer group among myopic students without glasses.

Outcome	Will wear glasses after myopia			
Sample	% Wearing glasses > Median (1)	% Wearing glasses < Median (2)	Average test scores > Median (3)	Average test scores < Median (4)
Control mean	0.498	0.398	0.446	0.453
Panel A. Specific nudge effect				
T1 (short-term)	0.045	0.071	0.092**	0.038
	(0.058)	(0.053)	(0.040)	(0.073)
T2 (long-term)	0.033	−0.005	0.071	−0.058
	(0.055)	(0.043)	(0.048)	(0.053)
T3 (prevalence)	0.033	0.031	0.093**	−0.023
	(0.045)	(0.044)	(0.043)	(0.057)
T4 (price)	0.111**	0.015	0.085*	0.047
	(0.049)	(0.048)	(0.043)	(0.045)
Observations	1046	996	1103	937
R-squared	0.193	0.160	0.172	0.175
Covariates & School-class FE	Yes	Yes	Yes	Yes
Panel B. Overall nudge effect				
Nudged	0.057	0.030	0.085***	0.001
	(0.041)	(0.035)	(0.030)	(0.044)
Observations	1046	996	1103	937
R-squared	0.190	0.158	0.171	0.170
Covariates & School-class FE	Yes	Yes	Yes	Yes

Notes: (1) Columns 1 and 2 show the peer groups in the ratio of wearing glasses in the class, while columns 3 and 4 show the peer groups in the average test scores in the class. (2) The median for the proportion of classmates wearing glasses was 35%, while the median for the average test scores of classmates was 140 points. (3) ***, **, and * indicate significance at the 1, 5, and 10 percent critical level based on robust standard errors clustered by school-class. (4) Coefficients significant at the 1% or 5% level remain significant after FDR adjustment.

than the median level (35%), while column (2) shows the results for those with fewer classmates wearing glasses than the median level. We find that only T4 had a statistically significant effect on those with more classmates wearing glasses, while none of the four treatment arms had a significant effect on those with fewer classmates wearing glasses. A plausible explanation is that students who were surrounded by more classmates wearing glasses were more likely to update their belief, when nudged by the information about glasses prices (T4).

Additionally, we also examined how nudge effects would vary with the peer effects of classmates' academic performance. In Table 7, column (3) reports the results for those whose classmates' average test scores were higher than the median level (140 points), while column (4) reports the results for those whose classmates' average test scores were lower than the median level. We find that all treatment arms except T2 had a statistically significant effect on those with more high-achieving classmates (T1 and T3 remain robust after adjusting p-values), while none of the four treatment arms had a significant effect on those with less high-achieving classmates. Besides, Panel B also shows a statistically significant overall nudge effect (8.5 pp, q-value: 0.034) on those with more high-achieving classmates, equivalent to a 19% increase from the control mean. This means that myopic students with more high-achieving classmates were 19% more willing to wear glasses after being nudged by the information. The pattern aligns with the heterogeneity in academic performance analyzed above, indicating that high-achieving classmates' self-efficacy might influence and motivate their peers to embrace useful information and modify their decisions.

5. Cost–benefit analysis

In this section, we conducted a cost–benefit analysis to assess the cost-effectiveness of this intervention project from a broader policy standpoint. But first, we need to measure the benefits of glasses-wearing in terms of students' academic performance.

5.1. Correlational evidence from the local sample

Students' test scores are used to evaluate the short-term benefits of wearing glasses. We employ cross-sectional administrative data on students' test scores, standardized at the school level, to examine the relationship myopia, glasses-wearing, and test scores. Due to the limitations of our cross-sectional dataset, we can only measure the correlation between students' academic performance, myopia, and glasses-wearing. Our regression model uses OLS and control the time students spent on studying to mitigate the selection bias associated with myopia.[10] The model specification is as follows:

$$Y_{i,s,c} = \beta_0 + \beta_1 Myopia_i + \beta_2 Wear\_glasses_i + \gamma X_i + \varphi_{s,c} + \varepsilon_{i,s,c} \quad (3)$$

where $Y_{i,s,c}$ is the test score in any of the three core subjects (Chinese, Math, or English), or their average test score, for a student i at school s and class c. $Myopia_i$ represents the whether the student i was diagnosed as myopia, and β_1 measures the correlation between myopia and the student's test score. $glasses_i$ represents whether the student i wore glasses, and β_2 measures the correlation between glasses-wearing and student's test score. X_i is a vector of covariates including student's personal characteristics. $\varphi_{s,c}$ is the school-class fixed effect. $\varepsilon_{i,s,c}$ is an error term, clustered by school-class.

Panel A in Table 8 shows the relationship of myopia and glasses-wearing with the test scores in Chinese (col. 1), Mathematics (col. 2), English (col. 3), and their average test scores (col. 4). We find that myopia negatively correlates with students' test scores across various subjects, while glasses-wearing consistently and positively correlates with students' test scores. Besides, the estimates show that students who wore glasses after myopia had higher test scores than non-myopic students in all three subjects. Specifically, students' Chinese and Mathematics test scores have the strongest correlation with myopia and glasses-wearing. Myopia has a negative correlation of 0.061 SD with Chinese or Mathematics test scores, while wearing glasses has a positive correlation of 0.131 SD with Mathematics test scores and a positive correlation of 0.122 SD with Chinese test scores. On average, myopia has a negative correlation of 0.051 SD with the average test scores of the three subjects, while wearing glasses has a positive correlation of 0.111 SD with the average test scores. This finding quantitatively aligns

[10] This bias stems from the notion that the harder a student works, the more likely they are to have vision problems.

Table 8
Effects of myopia and wearing glasses on academic performance (standardized test scores).

	(1) Chinese	(2) Mathematics	(3) English	(4) Average
Panel A: Local sample from this program				
Myopic (=1)	−0.061	−0.061**	−0.025	−0.051*
	(0.036)	(0.030)	(0.028)	(0.028)
Wear glasses (=1)	0.122***	0.131***	0.078**	0.111***
	(0.037)	(0.038)	(0.034)	(0.032)
Observations	7591	7577	7588	7576
R-squared	0.365	0.369	0.438	0.455
Panel B: Western rural samples from CEPS				
Myopic (=1)	−0.020	−0.029	−0.022	−0.026
	(0.037)	(0.034)	(0.044)	(0.025)
Wear glasses (=1)	0.025	0.076	0.009	0.038
	(0.056)	(0.059)	(0.053)	(0.042)
Observations	2317	2318	2314	2314
R-squared	0.536	0.580	0.624	0.735
Panel C: Nationwide samples from CEPS				
Myopic (=1)	−0.045**	−0.033*	−0.035	−0.037***
	(0.019)	(0.017)	(0.023)	(0.013)
Wear glasses (=1)	0.057**	0.042*	0.013	0.037**
	(0.023)	(0.022)	(0.023)	(0.016)
Observations	9318	9316	9309	9291
R-squared	0.55	0.577	0.663	0.748

Notes: (1) All test scores are standardized within schools. (2) CEPS is a nationwide survey in China that provides educational outcome data for students in grades 7 through 9. We utilize samples from grades 7 and 8. (3) Variable "Wear glasses" in Panel C shows the minimum effect of wearing glasses on test scores (4) Regressions include covariates and school-class fixed effects. (5) ***, **, and * indicate significance at the 1, 5, and 10 percent critical level based on robust standard errors clustered by school-class.

with the findings in Glewwe et al. (2016), which found that poor vision resulted in a 0.023 SD decrease in students' average test scores while having eyeglasses led to a 0.156 SD increase (LATE estimate).

5.2. Complementary evidence from the national sample

In this subsection, we resort to a nationally representative dataset to check the robustness of the relationship between myopia, glasses-wearing, and students' academic performance. While the panel structure alone does not guarantee strict causal identification due to potential time-varying unobservables, it allows us to control for prior academic achievement, thereby mitigating selection bias more effectively than cross-sectional correlations.

We employ the China Education Panel Survey (CEPS), a nationwide panel survey in China that provides educational outcome data for students in grades 7 through 9, and select students from grades 7 and 8 (same as our sample) to provide comparable results. To be specific, students from grades 7 and 8 represent the same individuals surveyed at different times, forming a panel data set. Therefore, we can employ a value-added model to estimate the effects of myopia and glasses-wearing on students' academic performance while controlling for their baseline ability.

In our regressions, students' test scores in grade 8 are the outcome variables, while grade 7 test scores are controlled as a lagged variable. Besides, our variables of interests, myopia and wearing glasses, were surveyed in grade 7 and preceded the grade 8 test scores.[11] Lastly, we also control the time students spent on their studies to mitigate the selection bias associated with developing myopia. The model specification is as follows:

$$Y_{i,s,c}^{g=8} = \beta_0 + Y_{i,s,c}^{g=7} + \beta_1 Myopia_i + \beta_2 Wear\_glasses_i + \gamma X_i + \varphi_{s,c} + \varepsilon_{i,s,c} \quad (4)$$

where $Y_{i,s,c}^{g=8}$ is the test score in any of the three core subjects (Chinese, Math, or English), or their average test score, for a student i in grade 8 at school s and class c. $Y_{i,s,c}^{g=7}$ is the corresponding test score of the student i recorded in grade 7. The rest of the equation remains unchanged compared to Eq. (3).

Panels B and C in Table 8 present the results from rural western samples, and nationwide samples, respectively. The rural western samples serve as an ideal counterpart to our local samples in terms of region and economic status. We find that wearing glasses after developing myopia led to consistent improvements in students' test scores across various subjects, especially for the nationwide sample shown in Panel C. However, unlike the correlation found in Panel A, it is shown that wearing glasses somehow failed to counteract the negative effects brought by myopia on English test scores.

Overall, the positive coefficients in the national sample align with the direction of our local estimates. Importantly, our local estimate of a 0.131 SD improvement is lower than the strict causal LATE estimate of 0.156 SD found in a similar randomized trial by Glewwe et al. (2016). This suggests that the coefficients utilized in our cost–benefit analysis likely represent a conservative lower-bound of the true benefits of wearing eyeglasses.

5.3. Calculation of the net benefits

Having measured the benefits of glasses-wearing for students' academic performance, we now proceed to calculate the net benefits of our informational nudge. Conservatively assuming that, without any other intervention and confounders, 10% of myopic students who were willing to wear glasses after the nudge would end up wearing glasses. Based on the assumption, there would be a 0.69 percentage point (10%× 6.9 pp = 0.69 pp) increase in eyeglass adoption for myopic students who receive T4. However, for minority girls who are myopic and receive T4, this increase rises to 1.57 percentage points (10% × 15.7 pp = 1.57 pp), representing the highest responsiveness among all subgroups.[12]

To value the academic benefit in our cost–benefit analysis, we use a shadow-pricing, or replacement-cost, approach. We value the test-score gain by asking what households pay for a similar gain through the nearest market substitute: private tutoring. This does not mean that glasses and tutoring are the same input. They work in different ways. Glasses help students see instruction clearly, while tutoring adds instruction. We use tutoring only as a market price for a similar test-score gain. Using a large-scale nationwide survey in China, Zhao (2015) shows that a 0.150 SD improvement in a student's Mathematics test score corresponds to RMB 1000 (or USD 137) in private tutoring spending. Applying this value to Panel A of Table 8, the 0.131 SD increase in Mathematics test scores associated with wearing glasses is worth about RMB 873.3 (or USD 120) per student.

This shadow price is conservative and likely understates the benefits of the intervention. First, private tutoring spending reflects what credit-constrained rural households can pay. It is therefore a market floor, not the full social value of the achievement gain. Estimates based on long-run labor-market returns to corrected vision and schooling are much higher (Boudreaux & Lipton, 2021; Naidoo et al., 2019). Second, the 0.131 SD effect is lower than the 0.156 SD causal estimate from the comparable randomized trial of Glewwe et al. (2016). Third, the calculation counts only academic gains. It leaves out direct health and quality-of-life benefits. All three choices make the estimated net benefit

[11] It is worth noting that CEPS did not survey whether students wore glasses when they were in grade 7. But we could infer who did not wear glasses, based on the information about myopia in grade 7 and information about glasses-wearing in grade 8. Then, we had 1969 myopic students we were not sure whether wore glasses in the grade 7. According to the literature, wearing glasses consistently improves the test scores of students with vision problems. Therefore, to obtain a lower-bound effect of wearing glasses on test scores, we regarded these 1969 students as wearing glasses.

[12] Zhang et al. (2022) found that the information nudges using message framing led to at least a 12 pp increase in students' eyeglasses ownership.

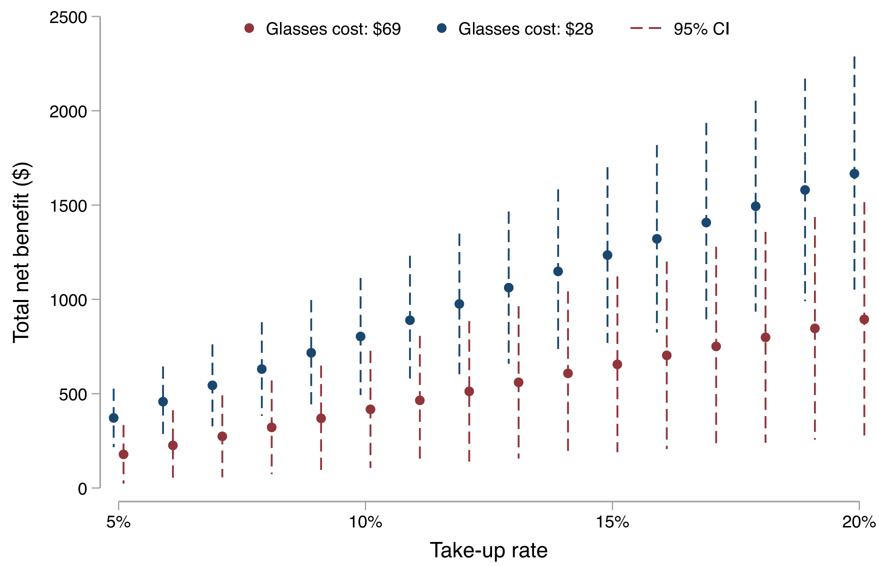

Fig. 4. Total net benefits across take-up rates.

smaller, so the positive net benefit reported below should be read as a conservative lower bound, not an exact point estimate.

To illustrate the potential maximum impact of the policy, we focus our cost–benefit calculation on this high-responsiveness subgroup (minority girls), effectively establishing an upper-bound scenario. If policymakers launch a campaign that delivers information nudges for 1000 myopic minority girls without glasses, about 16 of them would theoretically be nudged to wear glasses ($0.0157 \times 1000 \approx 16$). The glasses adoption would correlate with an increase of 0.131 SD in Mathematics test scores for each of those 16 students, which would otherwise cost \$1920 for 16 students' private tutoring to achieve the same improvement. Considering that our survey experiment had a per capita cost of approximately \$0.1 for digital delivery, and the average price of a pair of standard eyeglasses ranges from RMB 200 to RMB 500 (or USD 28 to USD 69) in China. The total costs of the campaign plus buying 16 pairs of standard glasses, each priced at USD 69, would be \$1204 at most ($\$0.1 \times 1000 + \$69 \times 16 = \$1204$). We can conclude that this targeted campaign yields a net benefit of at least \$716 in total or \$0.716 per capita. Applying the net benefit to our project, it amounts to a net benefit worth of approximately \$429.6 in total ($\$0.716 \times 600 = \$429.6$).[13]

To relax the specific assumptions from which the net benefit was derived, Fig. 4 illustrates how total net benefits vary with different take-up rates, glasses prices, and nudge effects in the scenario of nudging 1000 myopic minority girls. The figure includes take-up rates ranging from 5% to 20%, online prices of standard eyeglasses from USD 28 to USD 69, and the 95% confidence interval of the nudge effect (T4) on myopic minority girls. It is shown that the net benefit remains positive with the lowest take-up rate of 5%, the highest glasses price of USD 69, and the lower limit of nudge effect. This helps validate the cost-effectiveness of the information nudge we delivered.

6. Conclusion

Vision problems are among the most common factors undermining students' educational outcomes, yet they often remain untreated in low-income regions. This study examines whether low-cost information nudges can address behavioral barriers to glasses-wearing by shifting students' belief updating and stated preferences. In a lab-in-the-field experiment with 8262 middle school students in rural China, we find that information nudges increase stated willingness to wear glasses and to encourage peers to do so, but their effectiveness depends strongly on students' baseline circumstances and the specific barrier being targeted.

The results identify a clear window for targeted intervention. Nudges are most effective for students with recent myopia, before habituation to blurred vision appears to set in. Among myopic students without glasses, information on short-term academic benefits and glasses prices generates the largest gains in stated willingness to wear glasses. The mechanism analysis suggests that the nudges operate through both belief updating and salience: some students revise incorrect beliefs about myopia, peer prevalence, or prices, while others respond when already-known information becomes more decision-relevant. This distinction helps explain why different information arms work for different subgroups.

The heterogeneity results also support a precision approach rather than a blanket campaign. Minority girls, high-achieving students, and students embedded in peer environments where glasses-wearing is more visible are especially responsive. Because the intervention is inexpensive to deliver digitally, the cost–benefit analysis shows positive net benefits even under conservative assumptions.

The study has clear but manageable limitations. Our mechanism measures are proxies, not direct scales for stigma or long-term orientation. Our hukou-based economic-status proxy does not capture all household differences. The cost–benefit exercise uses a conservative market benchmark for academic gains, which likely understates benefits. Our data also cannot capture other structural barriers, such as the local availability of vision-care services or competing demands on household budgets. Measuring these directly is a useful direction for future work. These limitations do not weaken the main message: targeted information is a cost-effective way to move student beliefs and stated demand.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Supplementary materials

Supplementary material related to this article can be found online at https://doi.org/10.1016/j.econedurev.2026.102835.

[13] There are 600 myopic minority girls in our sample.

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