Invisible Disabilities and College Academic Success:

New Evidence from a Mediation Analysis*

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Abstract

Students with "invisible" disabilities—including autism spectrum disorder (ASD), attention deficit disorder (ADD/ADHD), learning disorders, and mental health conditions—make up an increasingly large share of college students in the United States. Despite these gains in access, students with invisible disabilities remain disadvantaged relative to their neurotypical and non-disabled peers in many parts of the college experience, including academically. Researchers have hypothesized that inequalities in pre-college academic preparation, barriers to social integration, and lower levels of engagement on college campuses may be at least partially to blame. We test this hypothesis using newly available survey data on college students in the state of Indiana. Based on a series of decompositions, we show that students with invisible disabilities face a series of interrelated challenges, beginning with their academic preparation and extending into their social and academic experiences on campus. That these disadvantages are interrelated suggests the presence of a cumulative advantage/disadvantage process, in which early advantages and disadvantages compound as disabled and non-disabled students move through the educational system and into college.

The educational outcomes of college students with "invisible" disabilities—including autism, attention deficit disorder (ADD/ADHD), learning disorders, and mental health conditions such as depression and anxiety—have received increased attention in recent years (see, e.g., Anderson et al. 2016; McLeod 2023; Sanford et al. 2011). This interest stems from the recognition that students with invisible disabilities represent a growing share of the overall college student population (Snyder, Brey, and Dillow 2018), but tend to fare worse academically and are less likely to graduate than their non-disabled peers (Magiati, Tay, and Howlin 2014; Newman et al. 2009; Wehman et al. 2014). Researchers have put forth several possible explanations for these differences, including inequalities in academic preparation, barriers to social integration, and gaps in engagement that place students with disabilities at a disadvantage relative to others (Carroll et al. 2020; Fleming, Plotner, and Oertle 2017).

Prior work examining the relative importance of these mechanisms has typically focused on important endpoints (such as college completion) using an additive approach that decomposes the total effects associated with disability status into direct and indirect components (see, e.g., Bruefach and Reynolds 2022; Carroll et al. 2020). Under this setup, researchers assume that mediators such as academic preparation and social integration are independent (i.e., they do not affect one another) and that indirect pathways through these variables do not overlap (i.e., there is only one indirect path that runs through each mediator) (VanderWeele 2015). This assumption would be violated if the barriers that college students with invisible disabilities face are causally ordered and *inter*dependent (Imai and Yamamoto 2013; Zhou and Yamamoto 2023), as would be the case if academic preparation for college predicted social integration and engagement once students arrive on campus.

Our primary objectives in this study are to (1) identify barriers to success among college students with invisible disabilities; and (2) consider the ways these barriers accumulate across students' secondary and post-secondary educational careers. To extend prior research, we implement a detailed approach to mediation analysis that can accommodate multiple causally related mediators (Mize, Doan,

and Long 2019). We use this approach to derive estimates of total, direct, and indirect effects and then trace the way these effects combine to influence students' college grades and risk of course failures—both of which are known antecedents of college completion. We argue that this exercise is critical for understanding the unique challenges students with invisible disabilities face and for identifying processes that impede or facilitate their post-secondary academic success.

Background

Disability is a broad category that can be disaggregated in several ways. We use the term "invisible disabilities" to refer to disabilities that are not immediately evident from a person's physical presentation. Learning disorders, ADD/ADHD, autism, mental health conditions including depression and anxiety disorders, and other conditions understood as involving behavioral, emotional, cognitive, or intellectual impairments all fit this description. Many of these conditions first present themselves at young ages or in early adulthood (Daniels and Mandell 2014)—which means that they, like race/ethnicity, class, and gender, begin to shape the life course early on and follow young people as they move through their lives (McLeod 2023).

Disability-related gaps in educational outcomes based on invisible disabilities are well documented. Throughout the K-12 years, autistic students tend to perform poorly on tests of reading comprehension, problem-solving skills, and math skills relative to typically developing students (Keen, Webster, and Ridley 2016). Symptoms of depression and anxiety are negatively associated with academic performance among school-age children as are learning disorders (Fergusson and Woodward 2002; Hinshaw 1992; Needham 2009; Needham, Crosnoe, and Muller 2004; Roeser, Eccles, and Strobel 1998). Although some studies have found that students with learning disorders are more likely than their peers to graduate from high school (McGee 2011), students with invisible disabilities are generally less likely than their peers to graduate on time (Breslau et al. 2011; Elbaum et al. 2014).

These gaps persist through the college years. College students with disabilities report lower

GPAs on average (Adams and Proctor 2010; Carroll, Muller, and Pattison 2016; Vogel and Adelman 1992; Wessel et al. 2009), are more likely to fail a course (Needham et al. 2004; Shifrer 2013), are less likely to persist at their current institution (Vogel and Adelman 1992; Wessel et al. 2009), take longer to graduate (Knight, Wessel, and Markle 2018; Wessel et al. 2009), and graduate at lower rates than their non-disabled counterparts (Adams and Proctor 2010; Fichten et al. 2014; Sanford et al. 2011). Among students with disabilities, students with invisible disabilities fare particularly poorly, experiencing lower rates of postsecondary enrollment, lower persistence, and lower graduation rates (Cortiella and Horowitz 2014; Lee et al. 2015; Pingry O'Neill, Markward, and French 2012; Sanford et al. 2011).

What gives rise to these differences? The literature on post-secondary success suggests a portion of the gap may be attributable to pre-college experiences and attributes (Kuh et al. 2006; Perna and Thomas 2006; Strayhorn 2018; Tinto 2006). Pre-college experiences and attributes encompass aspects of students' sociodemographic background (Buchmann, DiPrete, and McDaniel 2008; Fischer 2007; Kao and Thompson 2003), academic preparation (Adelman 2006; DesJardins and Lindsay 2008), and academic ability (Kobrin et al. 2008) that ease the transition to college-level coursework and facilitate social and academic integration in college life. Students with invisible disabilities, as a group, are at a disadvantage along all of these dimensions (Canu et al. 2021; Mazzotti et al. 2022; Yu et al. 2018). High school students with invisible disabilities are more likely to come from disadvantaged households than their classmates (Shifrer, Muller, and Callahan 2011), receive worse grades and lower levels of teacher support, and are given fewer opportunities to complete advanced coursework than those without invisible disabilities (Hitchings, Retish, and Horvath 2005; McLeod, Uemura, and Rohrman 2012; Shifrer, Callahan, and Muller 2013). Despite policies meant to guarantee quality primary and secondary education for students with disabilities (e.g., the Individuals with Disabilities Education Act (IDEA)), these gaps persist and may have consequences at the post-secondary level, where performance and completion are closely tied to academic readiness and social background (Allensworth and Clark

2020; Jackson and Kurlaender 2014).

Academic success at the post-secondary level also varies as a function of students' experiences in college, including the amount of time and effort students devote to their studies, how engaged they are with their coursework, and how integrated they are in campus activities. Students who are engaged in their college experience are more likely to persist, graduate on time, and tend to report greater satisfaction with their education and the institutions they attend (Astin 1997; Kuh 2009; Tinto 1993). This could present an obstacle for students with invisible disabilities. Researchers have found that college students with ADD/ADHD, ASD, learning disorders, and/or mental health problems report fewer friendships on average, are more likely to experience instances of physical or verbal bullying, and are less likely to be involved in a romantic relationship than their non-disabled peers (Jackson et al. 2018; McLeod, Meanwell, and Hawbaker 2019; White, Ollendick, and Bray 2011). They also tend to report lower levels of belonging on campus and are less likely to take advantage of collaborative learning opportunities (McLeod et al. 2019), to the possible detriment of their educational outcomes (Loes et al. 2017).

Research suggests that these two sources of disadvantage—in the resources students with invisible disabilities bring with them to college and in their level of engagement and social integration once they arrive—may be interrelated. Students who enter college with a solid academic foundation tend to experience greater confidence in their ability to succeed academically (Brown et al. 2008; Conley and French 2014; Lee et al. 2015). This confidence can contribute to a sense of belonging and engagement (Richardson, Abraham, and Bond 2012), as students feel capable and empowered to navigate the challenges they encounter at the post-secondary level (Ramos-Sánchez and Nichols 2007). The opposite may be true for students who are less equipped academically or who otherwise lack resources that enable a smooth transition into higher education (Hong 2015). We view this as a

potential example of a cumulative advantage process (DiPrete and Eirich 2006), where inequalities at one level of education lay the groundwork for additional inequalities at the next.

Empirical work examining barriers to success among students with invisible disabilities, although informative, has tended to proceed in a piecemeal fashion. Prior studies have either focused on the role of specific mediating processes (e.g., academic preparation or college engagement) for students with particular disabilities (see, e.g., Bruefach and Reynolds 2022; Field, Sarver, and Shaw 2003; Zilvinskis et al. 2023), or have used approaches that do not allow for accumulating advantages/disadvantages across different stages in the academic career (see, e.g., Carroll et al. 2020; Goegan and Daniels 2020; Kuriyan et al. 2013). This work has generally shown that both precollege academic preparation and experiences during college mediate the relationship between disability status and students' post-secondary educational success, albeit to varying degrees depending on the academic outcome under consideration and the disability in question. Researchers have not, however, been able to establish whether these processes are related or how advantages/disadvantages accumulate as students move through their high school and college years.

Our goal in the current study is to specify and test a model of college academic performance that (1) accommodates dependencies between students' academic preparation and their integration into college life; and (2) allows us to characterize the importance of these academic and social factors for autistic students, ADD/ADHD, learning disorders, mental health conditions, and/or other invisible disabilities. We see this as more than just a simple empirical exercise. Isolating the mechanisms that give rise to gaps in post-secondary academic outcomes by disability status—and investigating the way they feed into one another as students transition from high school to college—are important prerequisites if we wish to identify effective targets for intervention.

Data

Our analysis is based on data from an online survey of college students at ten Indiana colleges and

universities conducted in spring 2021. The survey was designed to evaluate differences in educational, occupational, and health outcomes between students with an autism spectrum disorder and neurotypical students. Because the sample of neurotypical students included a high proportion of students who reported a disability, we are also able to consider differences in outcomes based on disability status more generally defined. The survey was originally scheduled for administration in March 2020, when most colleges and universities sent students home in response to the COVID-19 pandemic and shifted to online instruction. Owing to the disruptions occasioned by the pandemic, we rescheduled survey administration to February and March 2021, when all the institutions in our sample had returned to in-person or hybrid instruction and students were back on campus.[1]

Sample

The study sample was selected in two stages: In the first stage, we selected institutions in the state of Indiana that were: (1) public or private not-for-profit, and (2) Associate's, Baccalaureate, Master's, or Doctoral universities. These criteria omit special-focus institutions such as seminaries and for-profit business schools. Based on these criteria, 46 institutions were eligible for the study. We further

[1] The COVID pandemic induced important changes in college life (Giuntella et al. 2021). Research shows that students from vulnerable groups—including students with invisible disabilities—were particularly affected (Halpern-Manners et al. 2023), leading to relatively higher rates of dropout and temporary withdrawal (Koopmann et al. 2023). Students with invisible disabilities who did *not* dropout or stopout may have benefited from stronger support systems, additional resources, more connections on campus, and more advantaged backgrounds. If anything, this form of *positive* selection should serve to attenuate differences between students with invisible disabilities and their non-disabled, neurotypical peers, leading to less pronounced inequalities in academic outcomes. This implies that our estimates of group differences may be conservative.

restricted the sample by size of institution, leaving out smaller schools (enrolled students ≤3000) that would not contribute enough students to meaningfully evaluate variation in outcomes across institutions. After this restriction, 16 institutions were eligible for the study. We contacted relevant administrators and directors of disability services offices at each campus; 13 agreed to participate, including three campuses of Indiana's community college network. By spring 2021, three of the institutions decided that they could no longer participate due to administrative challenges, leaving us with seven 4-year universities and three 2-year colleges.

In the second stage, at each participating institution, we invited two samples of students: (1) all students who were registered for disability accommodations based on autism and (2) a 20% probability sample of general population students. Autistic students who were registered with disability services—according to records maintained by each institution’s disability services office—were sampled with certainty to ensure adequate cell sizes. The sample was restricted to undergraduate students between the ages of 18–24 who were enrolled at the institution as of January 2021. No restrictions were put in place regarding year of study (which did not vary significantly by disability status), but high school and dual credit students were excluded from the sample. At nine of the ten institutions, the campus disability services office distributed survey invitations to registered students on our behalf and the Indiana Center for Survey Research distributed survey invitations to students in the general sample. One institution distributed the survey to both sets of students due to data privacy concerns.

Survey invitations were distributed by email. The initial survey invitation included study information and a survey link (personalized, for students in the general sample; anonymous, for students in registered samples). Students received up to four messages, consisting of the initial survey invitation and up to three reminders. The survey was administered between February and April 2021, with the timing of survey invitations and reminders varying slightly across institutions to accommodate differing term dates and spring break schedules.

The overall response rate for the general sample was 15.7%, with a range of 5.7%–32.5% across institutions. The registered samples had an overall response rate of 24.3% (range was 8%–83%). The cooperation rate was approximately 86%, meaning that 86% of the students who opened the recruitment email message and clicked on the survey link went on to complete the entire questionnaire. Comparisons of respondents and non-respondents—which were only possible for the general sample due to the way the survey was administered—revealed small differences with respect to racial/ethnic composition, age, and class standing, but more pronounced differences in terms of gender identity (men in the general sample responded at significantly lower rates than women). This form of differential nonresponse would bias our estimates if the relationship between disability status and college academic outcomes is conditional on gender (Groves and Couper 1998). Supplementary analyses—involving a series of by-gender interactions—suggest this is unlikely to be the case.

Measures

Study respondents completed a survey questionnaire implemented through Qualtrics. The questionnaire included close-ended and open-ended items adapted from several existing surveys of college students and young adults, including the National Survey of Student Engagement (NSSE), the National Longitudinal Study of Adolescent to Adult Health (Add Health), and the Wabash National Study of Liberal Arts Education Student Experiences Survey (WNS). Of particular interest in the present study are items measuring disability status, high school academic performance and course taking, college engagement and social integration, college grades, and college course failures. We describe these items in more detail below.

Disability status. Students were coded as having an invisible disability if they were in the registered sample and/or reported a lifetime diagnosis of autism, depression, post-traumatic stress disorder (PTSD), anxiety, attention deficit disorder (ADD/ADHD), a learning disorder, and/or some other

mental health condition.[2] While not ignoring the possibility that physical or sensory impairments shape students' academic experiences, such conditions were relatively rare in our sample, leaving us with little power to detect meaningful differences relative to neurotypical, nondisabled students. In our analyses, we disaggregated disability status into four mutually-exclusive categories: (1) non-disabled, neurotypical students; (2) students with a mental health diagnosis (depression, PTSD, anxiety, or other mental health condition); (3) students with a learning disorder or ADD/ADHD; and (4) autistic students.[3] We assigned disability codes using decision rules that gave precedence to the smallest disability group in instances where the respondent reported co-morbidities that would otherwise place them in more than one category (e.g., students who reported both autism and depression were included in the autism group because that group was smaller).

College preparation and high school academic achievement. Respondents were asked a series of questions about their academic experiences while in high school. Topics included high school grades (1 = mostly D's or below; 1.5 = C's and D's; 2 = mostly C's; 2.5 = B's and C's; 3 = mostly B's; 3.5 = A's and B's; 4 = mostly A's), highest level of math coursework (1 = calculus or above; 0 otherwise), foreign language study (response options ranged from 0 = I did not take foreign language to 4 = 4 years of foreign

[2] Autistic students typically register their condition with disability services, but prior research suggests that some students opt not to do so—either because they do not want additional support or because they encounter difficulties working with their school's disability service office (Kim and Crowley 2021). A similar pattern is evident in our data: out of the 75 students who self-reported an autism diagnosis as a part of the survey, 52 (or 69%) had registered their diagnosis with disability services.

[3] We grouped students with ADD/ADHD and learning disorders into a single category in part to avoid small cell sizes, but also because these groups often experience similar challenges when negotiating the unique academic demands of college (Connor 2012).

language), and whether they took any Advanced Placement, International Baccalaureate, and/or college-level courses prior to enrolling in college (1 = yes; 0 = no). Following prior research, we treat these self-reported items as general indicators of college preparation and academic achievement at the secondary level (see, e.g., Adelman 2006).[4]

College engagement and social integration. College experiences are measured with three scales meant to capture students' (1) perceived discrimination, (2) feelings of belonging on campus, and (3) level of involvement in college activities or clubs. To characterize students' experiences with discrimination, we asked respondents how often—since enrolling at their current institution—they have been treated with less respect than other people, people have acted as if they were not smart, they have been threatened or harassed, and people have acted as if they were better than them. These items were all taken from Williams et al.'s (1997) Everyday Discrimination Scale, with response options ranging from never (1) to almost every day (6) (α = .81). To gauge feelings of belonging, students were asked how much they agree or disagree with the following statements: it is easy for me to find people on campus with similar backgrounds, faculty show concern about my progress, faculty believe in my potential to succeed academically, people on campus help each other succeed, there is someone on campus I can trust to help me no matter what kind of help I need, I have close personal relationships with other students, and the student friendships I have developed are personally satisfying. Responses were on a four-point scale ranging from strongly disagree (1) to strongly agree (4) (α = .85). Finally, students were asked a series of yes/no questions about their involvement in activities on campus—including faculty research, a leadership position in a student organization, study abroad, service-learning

[4] Self-reported grades are an imperfect proxy for school-reported grades, but the relationship between the two is generally strong in college-based samples like ours (Kuncel, Credé, and Thomas 2005). There is reason to expect that the same holds for self-reported coursework (Sanchez and Buddin 2016).

or community-engaged learning courses, honors courses, Greek life, pre-professional or departmental clubs, other student clubs, and participation in sports (recreationally or intercollegiate). We summed responses across activities and then divided by the total number of items answered ($\alpha = .60$).

Post-secondary academic outcomes. Our measures of post-secondary academic outcomes include students' self-reported cumulative grade point average (GPA), and whether the participant had ever failed a course at their current institution (1 = yes; 0 = no). As shown in Table 1, the mean college GPA in our sample was 3.44 (SD = 0.48) and 18.7% of students reported failing at least one course. These numbers varied significantly by disability status [$F_{GPA} = 27.22$ ($df = 3$), $p_{GPA} < .01$, $\chi^2_{Fail} = 42.10$ ($df = 3$), $p_{Fail} < .01$], with autistic students reporting the lowest GPAs on average (3.22) and students with learning disorders failing courses at the highest rate (30.7%). The same figures for non-disabled, neurotypical students were 3.49 and 15.5%, respectively.

Sociodemographic characteristics. Students responded to questions about several sociodemographic characteristics, including race/ethnicity (American Indian or Alaska native, Asian, Black or African American, Hispanic or Latino, Native Hawaiian or Other Pacific Islander, White, or Other), gender identity (man, woman, intersex, transgender, other), parents' highest level of education (coded into a dichotomy where 1 = a Bachelor's degree or higher and 0 = otherwise), and respondents' subjective social status. We employ the MacArthur scale of subjective social status (see Adler and Stewart 2007), which asks respondents to rate themselves (relative to others) on a ten-point scale where 1 indicates the lowest and 10 indicates the highest social status in terms of money, education, and occupational prestige. Small racial/ethnic categories were consolidated into the residual other category to maintain adequate cell sizes, as were participants who identified with multiple racial/ethnic groups. Respondents' gender identities were consolidated into three categories (1 = male, 2 = female, 3 = other) for the same reason.

Modeling strategy

Our objective is to parse the pathways through which disability status shapes students' post-secondary academic performance. Unlike many mediation analyses, we are not focused on a single mediating variable or multiple mediators that bear no relation to one another. Instead, we view students' academic outcomes as the endpoint in a cumulative process driven by two broad sets of potentially interrelated factors: (1) precollege academic preparation and (2) academic and social experiences during college (e.g., Anderson and Butt 2017; Carroll et al. 2020; Cox et al. 2015; Gelbar, Shefyck, and Reichow 2015).

We provide a graphical display of this conceptualization in Figure 1. The diagram includes four sets of causally related variables: students' disability status (*X*), students' pre-college academic preparation (*HS*), students' college experiences (*COLL*), and students' post-secondary academic outcomes (*Y*). We hypothesize that these variables are related to each other through a series of direct and indirect pathways, as indicated by the arrows presented in the diagram.[5] The path from disability status to college performance ($X \rightarrow Y$) encodes the direct effect of disability status on college grades and course failures (i.e., effects on academic performance that are not transmitted by *HS* or *COLL*). The paths from disability status to college performance that travel through academic preparation ($X \rightarrow HS \rightarrow Y$ and $X \rightarrow HS \rightarrow COLL \rightarrow Y$) suggest the possibility of indirect effects via students' pre-college academic experiences. Finally, the path from disability status to college experiences ($X \rightarrow COLL \rightarrow Y$) suggests that there may be indirect effects via college experiences that bypass students' precollege academic preparation.

We recover estimates of $X \rightarrow Y$, $X \rightarrow HS \rightarrow Y$, $X \rightarrow HS \rightarrow COLL \rightarrow Y$, and $X \rightarrow COLL \rightarrow Y$ by simultaneously fitting four models:

[5] Covariates are omitted from Figure 1 for clarity, but all of our models adjust for students' socioeconomic background, race/ethnicity, and gender identity.

$$Y = f(X, B), \quad (1)$$

$$Y = f(X, B, HS), \quad (2)$$

$$Y = f(X, B, COLL), \quad (3)$$

$$Y = f(X, B, HS, COLL), \quad (4)$$

where Y is either college GPA or course failure; X, HS, and $COLL$ are the variables we defined above; B is a vector of sociodemographic characteristics that could act as confounds; and f is some function (e.g., OLS) that relates the left- and right-hand sides of the equalities. If assumptions about unconfoundedness hold (as we discuss in greater detail below), the estimate for X in Eq. (1) can be interpreted as the total effect of disability status on students' college academic outcomes. Differencing the estimate for X in Eqs. (1) and (4) provides an estimate of the indirect effect of X on Y, because Eq. (4) closes all of the indirect paths that connect the two variables (whereas Eq. (1) leaves them open). Subtracting this quantity from the total effect, in Eq. (1), yields an estimate of $X \rightarrow Y$.

Other cross-model comparisons are also informative. Comparing the estimate for X in Eqs. (3) and (4) provides the indirect effect that operates through pre-college academic preparation, or $X \rightarrow HS \rightarrow Y$. We call this a path-specific effect (PSE) because it traces a distinct indirect path in the diagram (Avin, Shpitser, and Pearl 2005). Differencing the estimate for X in Eqs. (2) and (4) yields a second PSE: the indirect effect that operates via students' college experiences, denoted above as $X \rightarrow COLL \rightarrow Y$. In both cases, the second equation (Eq. (4)) closes the pathway of interest (by conditioning on HS and $COLL$, respectively), whereas the first does not, allowing us to isolate the relevant PSE. Subtracting these PSEs ($X \rightarrow HS \rightarrow Y$ and $X \rightarrow COLL \rightarrow Y$) from the indirect effect of X on $COLL$, as defined above, provides a third and final PSE: the indirect effect of disability status that operates sequentially through both sets of mediators ($X \rightarrow HS \rightarrow COLL \rightarrow Y$).

We use the approach described in Mize, Doan, and Long (2019) to carry out cross-model comparisons and recover within- and cross-model variance and covariance estimates. These estimates

are then used to produce test statistics and *p*-values for the direct effect of disability status (*D→Y*), the combined indirect effect of *D* on *Y* (summing across all indirect pathways), and each of the PSEs (*X→HS→Y, X→COLL→Y,* and *X→HS→COLL→Y*) (see Mize et al. 2019 for more details). In models predicting course failure, we fit logistic regressions and then computed average marginal effects (AMEs) before making cross-model comparisons. AMEs eliminate concerns about rescaling (Karlson, Holm, and Breen 2012; Mize et al. 2019; Mood 2010; Winship and Mare 1984), and allow us to proceed more naturally in the metric of probabilities. Raw coefficients from models predicting course failure are provided in Appendix Table A1.

Identifying direct, indirect, and path-specific effects requires that the disability status-mediators, disability status-outcomes, mediators-mediators, and mediators-outcomes relationships are unconfounded. This means that—after conditioning on students' sociodemographic characteristics—there are no unobserved variables that predict (1) disability status, precollege academic preparation, and students' social and academic integration at college; (2) disability status and college academic performance; (3) precollege academic preparation and social and academic integration at the post-secondary level; and/or (4) precollege academic preparation, social and academic integration, and students' academic outcomes in college. Although we cannot test these requirements directly, we can perform sensitivity analyses designed to evaluate the robustness of our estimates to potential violations. We present results from this exercise after summarizing our main findings.

Results

Total effects

We begin by presenting two sets of estimates of college achievement gaps between (1) non-disabled, neurotypical students, (2) students with a mental health condition, (3) students with a learning disorder or ADHD/ADD, and (4) autistic students. The first set of estimates—given in the leftmost column of results of Table 2—makes no adjustment for differences by disability status in students'

sociodemographic characteristics. These estimates mirror the raw gaps we reported in Table 1. The second set of estimates—given in the second column of results in Table 2—was obtained from models that incorporated our full set of controls, as specified in Eq. (1). Together, these estimates provide a sense for the total effects of disability status net of covariates and the role that sociodemographic variables play as confounds.

The results indicate that students with disabilities tend to perform worse in college than non-disabled, neurotypical students and that the discrepancy cannot be attributed to group differences in social background or demographic characteristics. Although significant gaps were evident for all three disability groups, they were especially pronounced for students with learning disorders and autistic students. For students with learning disorders, the probability of failing a course was 14.8 percentage points higher than among non-disabled, neurotypical students (95% CI = 0.090 to 0.207, $p < .01$), and their GPAs were 0.260 points lower after adjusting for background characteristics (95% CI = -0.321 to -0.198, $p < .01$). The latter point estimate is nearly equivalent to half a letter grade on a four-point scale. For autistic students, the probability of failing a course was 8.3 percentage points higher than among non-disabled, neurotypical students (95% CI = -0.011 to 0.177, $p < .10$), and their GPAs were 0.250 points lower on average (95% CI = -0.357 to -0.143, $p < .01$).

Effect decomposition

Our primary objective is to decompose gaps in college academic performance into direct and indirect effects transmitted via students' high school preparation and collegiate experiences. Figures 2 and 3 provide the relevant estimates, with results disaggregated according to the outcome under consideration. The stacked bars in each plot show the total effect associated with a given disability—as summarized in the previous section—and the portion of that effect that operates via a specific pathway. There are four pathways in total: effects that operate through high school academic preparation (*HS*) only (shown in blue), effects that operate through college engagement/social integration (*COLL*) only

(shown in green), effects that operate through high school preparation and college engagement/social integration (shown in yellow), and direct effects that operate via other channels (shown in purple).

For both academic outcomes and for all three groups of students with disabilities, high school academic preparation appears to be particularly consequential. This is in part because there is a direct link between disability status, pre-college academic preparation, and college academic performance ($X \rightarrow HS \rightarrow Y$). On its own, high school academic preparation explained 36.4% of the GPA gap between neurotypical, non-disabled students and students with a learning disorder ($p < .01$), 30.6% of the GPA gap between neurotypical, non-disabled students and autistic students ($p < .01$), and 38.9% of the GPA gap between neurotypical, non-disabled students and students with a mental health condition ($p < .01$). Parallel estimates from models predicting college course failure(s)—34.5% ($p < .01$), 39.1% ($p < .05$), and 21.5% ($p < .01$), respectively—were generally similar.

High school academic preparation also matters because it shapes students' social and academic experiences after they transition to college. Our estimated PSEs for the path connecting disability status to academic preparation and students' post-secondary experiences ($X \rightarrow HS \rightarrow COLL \rightarrow Y$), although smaller in magnitude, were statistically significant for autistic students (percent mediated = 7.6%; $p < .01$) and students with a learning disorder (percent mediated = 4.2%; $p < .01$) in our model predicting college GPA and for autistic students (percent mediated = 8.8%; $p < .05$) in our model predicting college course failure. For these students, advantages/disadvantages in high school appear to lay the groundwork for additional advantages/disadvantages in college, with direct implications for their post-secondary academic performance.

The last set of PSEs—describing the path that bypasses high school academic preparation but travels through college experiences ($X \rightarrow COLL \rightarrow Y$)—are also noteworthy, at least for certain disability groups. According to our estimates, they explain 6.6% of the GPA gap between autistic students and neurotypical, non-disabled students ($p < .10$), and 11.6% of the autism-neurotypical gap in the

probability of failing at least one college course ($p < .10$). The corresponding figures for students with a mental health condition were 16.4% ($p < .01$) and 13.4% ($p < .01$), respectively. These estimates suggest that, even independent of their high school academic preparation, students with invisible disabilities may have difficulty integrating socially and academically at the college level, placing them at a disadvantage with respect to important post-secondary outcomes.

Robustness checks

As noted earlier, our inferences about the effects of disability status on college academic performance depend on untestable assumptions about unconfoundedness (VanderWeele 2015). To consider the implications of violating these assumptions, we calculated a series of E-values using the framework proposed by Vanderweele and Ding (2017). E-values provide a convenient metric for quantifying the amount of unobserved confounding that would be needed to produce an observed effect, including indirect effects in settings where mediation is of interest (Smith and VanderWeele 2019). Larger E-values indicate that considerable unmeasured confounding would be needed to explain away an effect estimate, whereas smaller E-values indicate the opposite. This framework is useful for our purposes because it does not require us to specify the strength, form, number, or pattern of association of the unobserved confounds.

Table 3 provides E-values for the total, direct, and indirect effects (summing across PSEs) reported above. The estimates range in magnitude from 2.62 (for the total effect of a learning disorder or ADD/ADHD on GPA) to 1.28 (for the indirect effect of a mental health diagnosis on course failure). These results imply, for instance, that an unobserved confound would need to increase the probability of a learning disorder by 162 percent, while having an equally sized effect on GPA, in order to account for the total effect of a learning disorder on students' college grades. Even a variable like gender—which strongly predicts disability status and both of the academic outcomes that we consider—does not satisfy

these requirements after conditioning on the other variables in our model.[6] Although we prefer to be as circumspect as possible when making causal statements, we think these results provide at least some reassurance against the threat of unobserved confounding.

Discussion

Students with "invisible" disabilities make up an increasingly large share of college students in the U.S. (Snyder et al. 2018). Despite these gains in access, students with invisible disabilities remain disadvantaged relative to their neurotypical and non-disabled peers in many parts of the college experience, including academically (Wehman et al. 2014). Researchers have hypothesized that inequalities in pre-college academic preparation, barriers to social integration, and lower levels of engagement on college campuses may be at least partially to blame (e.g., Carroll et al. 2020). We sought to test this hypothesis using newly available survey data on the college experiences of two- and four-year college students in the state of Indiana. Our approach exploited recent advances in mediation analysis to pinpoint specific pathways through which advantages and disadvantages operate as students move through their secondary and post-secondary years.

Our results indicate that academic preparation and precollege achievement are key mechanisms driving gaps between students with invisible disabilities and their non-disabled peers, in part because they establish a foundation for academic success once high school students matriculate—but also because they influence students' engagement and sense of belonging at the post-secondary level. This result was generally consistent across measures of college academic performance and was apparent, to varying degrees, for each of the disability categories we considered. We interpret this as evidence of a cumulative advantage process, in which educational advantages and disadvantages compound over time

[6] For context, male students were 1.25 times more likely to report failing a course than female students, net of social background.

as students transition across educational levels. The same skills and resources that benefit students in high school also benefit them in college, because they (1) are rewarded in the classroom *and* (2) facilitate social integration and feelings of belonging that further enable students' academic success.

What do these findings mean for students with invisible disabilities and the schools that serve them? Large bodies of literature focus on the college experiences of minoritized and/or first-generation college students (see, e.g., Minikel-Lacocque 2013; Owens and Lynch 2012; Walpole 2008; Walton and Cohen 2011; Wilbur and Roscigno 2016), and many colleges and universities have dedicated programs in place that are designed to ease the high school-to-college transition for members of these groups. Our findings suggest that students with invisible disabilities could benefit from similar services and institutional supports. Forms of academic remediation that aim to be inclusive of students who are on the margins of college readiness—but that do not isolate them socially or academically from their peers—may be especially useful as students with invisible disabilities navigate the challenges of adapting to all aspects of college life (see, e.g., Ran and Lin 2022).

Redressing academic inequities that exist prior to college enrollment would also be beneficial. The estimates we obtained from our decomposition analysis point unequivocally—and perhaps unsurprisingly—to the importance of precollege academic preparation in the production of gaps in college academic performance. Our descriptive results show that students with invisible disabilities had lower high school GPAs, on average, and were less likely to take calculus in high school than neurotypical and non-disabled students. They also show that students with autism or a learning disorder took fewer years of a foreign language in high school and were less likely to take an AP course compared to their non-disabled peers. Remediating these gaps in preparation—through targeted, evidence-based interventions (see, e.g., Hock et al. 2017)—may help attenuate disparities in performance at the post-secondary level.

We offer these conclusions alongside some important caveats. First, our sampling strategy in the

first stage was not random (schools self-selected into the study), which means the students who ultimately participated may not be representative of students in the broader population. This—coupled with relatively low response rates, the timing of the survey relative to the COVID pandemic, and geographic restrictions—raises concerns about generalizability. Second, the information that students provided regarding disabilities was subject to misreporting. We think the most likely scenario involves underreporting due to the stigma associated with invisible disabilities and possible concerns about disclosure.[7] This behavior would have the consequence of downwardly biasing our estimates of gaps between disabled and non-disabled students (due to the presence of disabled students in the non-disabled group), resulting in an overly conservative picture of inequalities in students' academic performance. Third, the classification scheme we used to assign students to disability groups was imperfect. We were unable to consider comorbidities due to small cell sizes, and we used dichotomous classifications when (at least in the case of autism) a continuous measure (that captures the full range of autistic traits) may have yielded additional information.

We do not think these qualifications negate the overall importance of our findings. National estimates indicate that approximately two-thirds of high school students with ASD, ADD/ADHD, or a learning disorder go on to pursue a post-secondary degree (Hinz, Arbeit, and Bentz 2017), and that roughly 20 percent of college students report a disability of one form or another (Snyder et al. 2018). How these students fare in college—and the complex set of processes that enable or inhibit their success at the post-secondary level—are critical issues for education researchers and others who are interested in disability as an axis of inequality. What our analyses show is that students with invisible

[7] Although the amount of underreporting for conditions other than autism is unclear, students' self-reported autism diagnoses appear to be quite accurate (96% of students in the registered sample disclosed an autism diagnosis when asked on the survey).

disabilities face a series of interrelated challenges, extending from their precollege academic preparation to their social and academic experiences on campus. Addressing these challenges in a meaningful way will require careful attention to the way they accumulate and compound as students make their way through the educational system.

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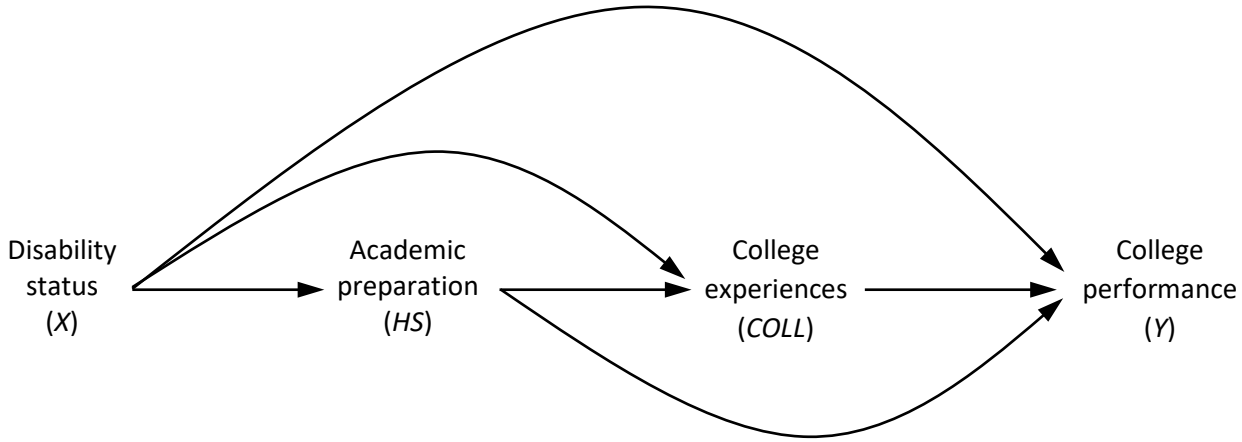

Figure 1. Proposed pathways connecting disability status to academic performance in college. Our analyses allow for direct effects of disability status on performance (*X*→*Y*) and indirect effects that travel through academic preparation (*X*→*HS*→*Y*), college experiences (*X*→*COLL*→*Y*), and academic preparation and college experiences (*X*→*HS*→*COLL*→*Y*). See text for more details.

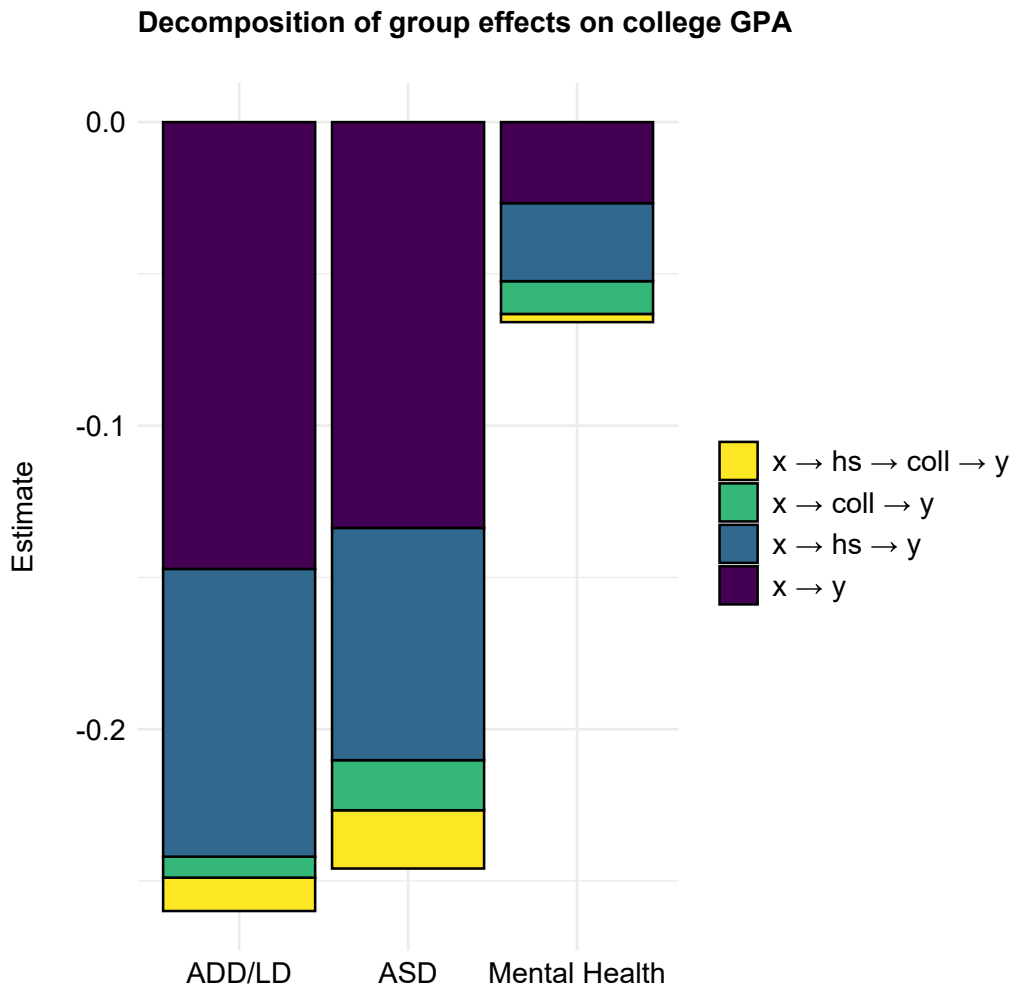

Figure 2: Decomposition of the relationship between group membership and college GPA. Estimates for students with a learning disorder or ADD/ADHD (ADD/LD), autistic students (ASD), and students with other mental health conditions (Mental Health) are relative to non-disabled, neurotypical students. We decomposed the estimated effects into four components: effects that operate through high school preparation only (x $\rightarrow$ hs $\rightarrow$ y), effects that operate through college engagement/campus integration only (x $\rightarrow$ coll $\rightarrow$ y), effects that operate through high school preparation and college engagement (x $\rightarrow$ hs $\rightarrow$ coll $\rightarrow$ y), and effects that operate through other channels (x $\rightarrow$ y). See text for more details.

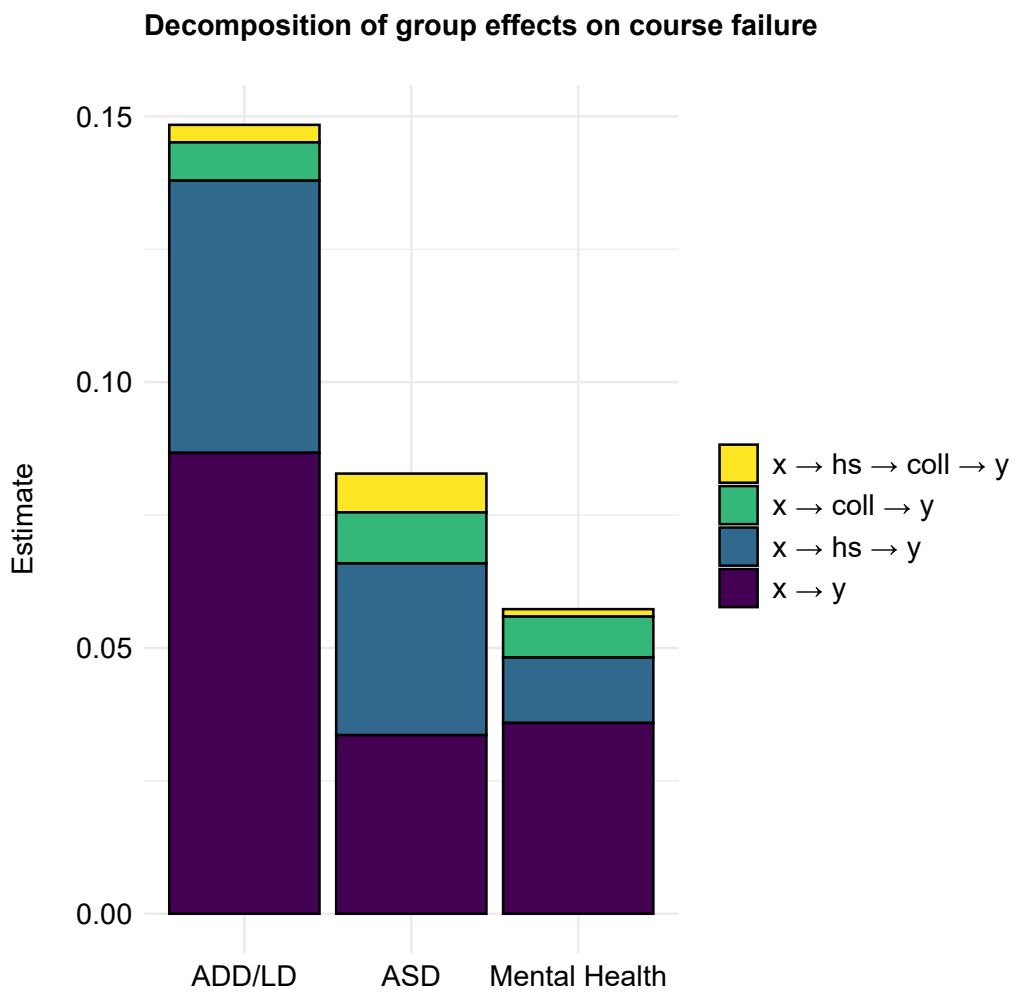

Figure 3: Decomposition of the relationship between group membership and college course failure. Estimates for students with a learning disorder or ADD/ADHD (ADD/LD), autistic students (ASD), and students with other mental health conditions (Mental Health) are relative to non-disabled, neurotypical students. Estimates represent average marginal effects on the probability of a course failure conditional on group membership. We decomposed the estimated effects into four components: effects that operate through high school preparation only (x $\rightarrow$ hs $\rightarrow$ y), effects that operate through college engagement/campus integration only (x $\rightarrow$ coll $\rightarrow$ y), effects that operate through high school preparation and college engagement (x $\rightarrow$ hs $\rightarrow$ coll $\rightarrow$ y), and effects that operate through other channels (x $\rightarrow$ y). See text for more details.

Table 1. Descriptive statistics by disability status

	Disability group				
	Autistic students	Mental health condition	Learning disorder/ ADD/ADHD	Neurotypical, non-disabled	Total
College academic performance					
College GPA	3.22	3.42	3.23	3.49	3.44
	(0.71)	(0.48)	(0.60)	(0.44)	(0.48)
Failed 1+ course (%)	25.64	21.60	30.65	15.52	18.73
Mediators					
Took calculus or above (%)	29.49	47.58	31.42	57.73	51.94
Took an AP course (%)	67.95	89.58	80.46	85.64	85.59
High school GPA	3.54	3.66	3.46	3.74	3.70
	(0.46)	(0.46)	(0.49)	(0.37)	(0.41)
Years of foreign language in HS	2.60	3.17	2.96	3.13	3.11
	(1.32)	(0.83)	(0.91)	(0.86)	(0.88)
Campus social integration scale	2.83	2.92	2.98	3.03	2.99
	(0.60)	(0.58)	(0.56)	(0.55)	(0.56)
Everyday discrimination scale	2.01	2.17	2.16	1.91	2.00
	(1.12)	(0.96)	(0.94)	(0.84)	(0.90)
Campus engagement scale	1.91	2.38	2.27	2.48	2.42
	(1.62)	(1.88)	(1.79)	(1.86)	(1.86)
Covariates					
Race/ethnicity (%)					
Non-Hispanic White	87.18	76.59	82.76	66.47	71.08
Non-Hispanic Black	3.85	4.38	1.92	5.04	4.55
Hispanic	2.56	7.40	6.51	7.93	7.51
Non-Hispanic Asian or Pac. Isl.	2.56	5.59	3.45	15.98	11.88
Other	3.85	6.04	5.36	4.57	4.99
Gender identity (%)					
Male	58.97	14.05	29.12	42.33	34.68
Female	30.77	82.18	67.05	56.98	63.31
Other	10.26	3.78	3.83	0.69	2.02
Max of parental education (years)	16.81	15.84	16.25	16.16	16.11
	(2.39)	(2.61)	(2.26)	(2.51)	(2.51)
Subjective social status growing up	6.59	6.26	6.32	6.79	6.61
	(1.69)	(1.57)	(1.71)	(1.49)	(1.56)
n	78	662	261	1727	2728

Note: Percentages reported for categorical variables. Standard deviations reported in parentheses for continuous variables. See text for more details.

Table 2. Estimates of total effects of disability status on college academic performance

	M1	M2
A. Models predicting college GPA		
Neurotypical, non-disabled (Ref.)	-	-
	-	-
Mental health condition	**-0.067**	**-0.066**
	(0.022)	(0.022)
Learning disorder/ADD	**-0.262**	**-0.260**
	(0.032)	(0.031)
Autistic students	**-0.268**	**-0.250**
	(0.055)	(0.055)
Covariate adjustment		✓
B. Models predicting college course failure		
Neurotypical, non-disabled (Ref.)	-	-
	-	-
Mental health condition	**0.061**	**0.057**
	(0.018)	(0.019)
Learning disorder/ADD	**0.151**	**0.148**
	(0.030)	(0.030)
Autistic students	**0.101**	0.083
	(0.050)	(0.048)
Covariate adjustment		✓

Note: Model 1 (M1) does not adjust for students' sociodemographic characteristics; Model 2 (M2) adjusts for our full set of controls (i.e., race/ethnicity, gender identity, parental education, and subjective social status while growing up). The estimates in panel A are coefficients obtained from OLS models; the estimates in panel B are average marginal effects (AMEs). Bolded coefficients are at least two times their standard error. See text for more details.

Table 3. E-values by disability group, effect type, and outcome

	E-values		
	Total effect	Direct effect	Indirect effect
A. Models predicting college GPA			
Mental health condition	1.52	1.28	1.37
Learning disorder/ADD	2.62	1.96	1.77
Autistic students	2.57	1.91	1.77
B. Models predicting college course failure			
Mental health condition	1.55	1.40	1.28
Learning disorder/ADD	2.19	1.75	1.58
Autistic students	1.72	1.38	1.49

Note: E-values were obtained after fitting models predicting college GPA (panel A) and college course failure (panel B). See text for more details.

Appendix Table A1. Log odds of course failure by disability status and social background

	M1	M2
Neurotypical, non-disabled (Ref.)	-	-
	-	-
Mental health condition	**0.405**	**0.395**
	(0.115)	(0.124)
Learning disorder	**0.878**	**0.891**
	(0.150)	(0.156)
Autistic students	**0.630**	0.545
	(0.268)	(0.278)
Race/ethnicity (%)		
Non-Hispanic White (Ref.)		-
		-
Non-Hispanic Black		**0.895**
		(0.207)
Hispanic		**0.585**
		(0.173)
Non-Hispanic Asian or Pac. Isl.		-0.100
		(0.177)
Other		**0.518**
		(0.208)
Gender identity (%)		
Male (Ref.)		-
		-
Female		**-0.364**
		(0.111)
Other		0.395
		(0.307)
Max of parental education (years)		-0.037
		(0.021)
Subjective social status growing up		**-0.146**
		(0.034)

Note: Model 1 (M1) does not adjust for students' sociodemographic characteristics; Model 2 (M2) adjusts for our full set of controls (i.e., race/ethnicity, gender identity, parental education, and subjective social status while growing up). Bolded coefficients are at least two times their standard error. See the main text for more details.