**ACADEMIC SUPPORTS, COGNITIVE DISABILITY AND
MATHEMATICS ACHEIVEMENT FOR VISUALLY IMPARIED YOUTH:
A MULTILEVEL MODELING APPROACH**

J. Martin Giesen
Brenda S. Cavenaugh
Michele Capella McDonnall
Mississippi State University

*Elementary and middle school students who are blind or visually impaired (VI) lag up
to three years behind non-disabled peers in mathematics achievement. We investigated
the impact of academic supports in the school on mathematics achievement,
controlling grade, gender, cognitive disability, and family SES. Data were from SEELS
(Special Education Elementary Longitudinal Study) that followed a national sample of
students over six years. Analyses employed multilevel modeling. We found the extent of
academic supports in the school was positively related to mathematics achievement for
visually impaired (VI) students without cognitive disability but not for those with
cognitive disability. Gender and socio-economic status (SES) had no effects.
Achievement growth was not hampered by cognitive disability. Schools with more
academic supports may enhance mathematics learning for VI students without a
cognitive disability, and VI students with a cognitive disability may need both a high
level of supports and specialized supports to facilitate mathematics achievement.
Keywords: mathematics achievement, blind, visually impaired, academic supports,
cognitive disability.*

Introduction
Poor mathematics achievement in students with little or no useful vision has long been a concern of
blindness practitioners, administrators, parents, and consumer groups. Over the years, strategies have
been developed to overcome the multiple challenges that blind students face in learning mathematics.
With the development of a braille math and science code by Dr. Abraham Nemeth in the late 1940's,
blind students were able to read previously inaccessible mathematical text independently (National
Center for Blind Youth in Science, 2010). More recently, software tutorials have been developed to assist
both teachers and students in learning the Nemeth Braille Code for Mathematics and Science
(Kapperman & Sticken, 2002) and to assist students in solving math word problems (Beal & Shaw,
2008). Summer programs and camps have been established to provide children and youth with visual
impairments (including those who are blind or have low vision) with hands-on experiences and
knowledge of science, technology, engineering, and mathematics careers (e.g., National Federation of the
Blind Youth Slam and Junior Science Academy; Space Camp for Interested Visually Impaired Students).
Information sharing has continued to increase with access to multiple online resources. For example, the
Texas School for the Blind (2008) maintains a comprehensive website on teaching math to visually
impaired (VI) students. The website serves as a one-stop center where educators and rehabilitation
practitioners can download instructional materials and access information about a variety of topics,
including teaching strategies, math tools and resources, and ongoing research projects.

Mathematics Achievement of VI Students
Although anecdotal evidence suggests that VI students lag behind their sighted peers in mathematics
achievement, there has been little empirical research to verify this claim. This is partially because of the
difficulty of acquiring adequate samples of VI students. However, recent studies employing large-scale,
nationally-representative longitudinal samples have confirmed lags of approximately one-half year for
students ages 7 through 12 (Blackorby & Cameto, 2004) and three years for students ages 13 through 16
(Blackorby, Chorost, Garza, & Guzman, 2003). Reports of statewide educational assessments are

typically aggregated across all special education students. Findings from the few States reporting data disaggregated by type of disability have shown that VI students have lower math scores than their nondisabled peers (e.g., North Carolina State Board of Education, 2009; Winford, 2003).

Visual Impairment and Additional Disabilities
The above findings were based on students with a *primary* disability of visual impairment and *excluded* VI students who were designated as having some other primary disability (e.g., learning disabilities, orthopedic impairments, hearing impairments, multiple disabilities). These *other VI* students have visual impairments plus some other primary disability, thus having VI as a presumed *secondary* disability. This population may be larger than that with VI as a primary disability. For example, Kirchner and Diament (1999) estimated that more than 50% of all VI students, birth-21 years, had at least one other disability. There has been a concern for some time among blindness and low vision educators (e.g., Mason & Davidson, 2000) that exclusion of these students from studies can lead to misinterpretations of the educational needs of VI students. Thus, inclusion of students with both specifications of VI status (primary or secondary) is important for comprehensive research involving VI students.

Instructional Needs of VI Students
A majority of students with a primary disability of VI are being taught in regular classrooms at least 80% of the school day (United States Office of Special Education Programs, 2007), but adequate supports are often not available (Mason & Davidson, 2000). Clearly, VI students have special instructional needs to access academic subjects, including academic supports and specialized curricula (American Foundation for the Blind, 2005). Students with visual impairments (given opportunities for meaningful participation in classes, teachers adequately trained in specialized vision services, and other appropriate academic supports) may be expected to have the potential to achieve in mathematics on a par with their non-disabled peers (Kapperman & Sticken, 2003).

Student Supports
Student academic supports represent an important potential component in the mathematics achievement of VI students. Supports are considered those services, resources, or special programs offered to students outside of regular classes, including before or after school hours. Academic supports relate specifically to academic activities considered to have a significant influence on mathematics achievement (e.g., supplemental instruction, tutoring or mentoring, other after school programs). A nationally representative sample of school principals identified supplemental instructional programs (including before, after school, or weekend programs) as one of five major strategies for improving academic achievement of students. Other studies have also identified academic supports such as supplemental instruction, tutoring, and mentoring as characteristics of highly effective schools (Fundukian, 2009; Odden & Archibald, 2009; Williams & Kirst, 2006) and in particular, schools with highly effective mathematics instruction (Kitchen, DePree, Celedón-Pattichis, & Brinkerhoff, 2004). Although academic supports have been implied to be helpful in mathematics learning for students who are visually impaired, empirical evidence is lacking in this regard. The relationship between *academic supports in the school* and *mathematics achievement* for students who are visually impaired is the focus of this study.

Given this background, our main general research question is whether an environment with more academic support is helpful for VI students. Specifically, we investigated the associations of the extent of academic supports available in the school of the student with initial level and growth in mathematics achievement for VI students over time. Academic supports in schools were expected to be positively associated with mathematics achievement. Cognitive disability, gender, and family socioeconomic status were included as contextual and possible moderator variables. Having a cognitive disability is known to affect math achievement scores, so it was considered important to include this factor (Blackorby, Knokey, Wagner, Levine, Schiller, & Sumi, 2007). Likewise, gender and family SES were included due to their expected influences on achievement (e.g., Demery, 2000). Specific research questions were as follows.

1. Are more academic supports available in the school associated with higher mathematics achievement (initial level & growth over time)?
2. To what extent is any relationship between academic supports and mathematics achievement moderated by cognitive disability, gender, or family SES?

Method
Data Source
Data were from Special Education Elementary Longitudinal Study, 2007,(SEELS) conducted by SRI International, funded by, and available as restricted-use data from the Office of Special Education Programs (OSEP). SEELS (SEELS Home & News, 2008) was a six-year study (2000-2006) designed to assess change over time. It followed a nationally representative sample of approximately 13,000 special education students' ages 6 to 12 at outset. The sample was identified by a two-stage process that first involved identification of a stratified sample of local education agencies (LEA) and state-supported schools for students with disabilities. The stratification was based on geographic region, district size, and district/community wealth. In the second stage, there was a random selection of students for participation from rosters of special education students in the schools in these LEAs and the schools for students with disabilities. Data were collected at up to three time points (measurement waves at 2000/2001, 2002, 2004) through direct assessment of students and via a variety of interviews and surveys of parents, teachers, and principals. Direct assessments of students included measures of achievement, academic performance, self-concept, and attitudes toward school. Data collection in other areas included students' family characteristics; nons-chool activities; classroom experiences; instructional goals; accommodations; school programs, policies and practices; and family, school, and social context and climate. All school-level data were available only as linked at the student level. Thus, SEELS comprehensively documented the achievement, personal characteristics, and educational experiences of a sample of elementary special education students as they moved through the school system from elementary school to high school.

Selection of Sample
Data were initially limited to students with visual impairments including blindness. These students were identified by either (a) having a primary disability of visual impairment (one of the 13 special education disability categories), or (b) being identified by a parent or teacher as having a visual impairment, even when this was not their primary disability. Students identified as deaf-blind were not included. A further limitation of the sample was some lack of availability of data on the primary outcome measure of mathematics achievement. We included students identified as having a visual impairment (as previously described) and also those who had scores available on the mathematics achievement measure for at least one of the three measurement time points. Students also needed scores present on the focal predictors and control variables, altogether yielding a final $N = 292$.

Primary Outcome and Explanatory Measures
Outcome Measure of Mathematics Achievement. The Applied Problems subtest of the Woodcock-Johnson III Tests of Achievement (WJ-III ACH) covers the curricular area of mathematics and the ability areas of quantitative reasoning, mathematics achievement, and mathematics knowledge. It involves both auditory and visual stimuli and requires the student to perform mathematics calculations in response to orally presented problems. Students respond orally to the problems (Schrank, McGrew, & Woodcock, 2001).

On the WJ III ACH, the W scores available are Rasch-scaled scores that have the quality of equal interval units. The W score mean is centered to a value of 500, corresponding to approximately the average performance of students beginning the 5th grade (Woodcock, McGrew, & Mather, 2001). Because the W score is not grade-level normed and has a fixed setting to 5th grade student performance, it is ideal for use in longitudinal analyses.

As an instrument to measure achievement, the WJ-III ACH has been considered the best available according to reviewers in the 15th Mental Measurements Yearbook (Cizek, 2003; Sandoval, 2003). Bases for development of the test included the Cattell-Horn-Carroll theory of cognitive abilities, educational core curricular areas, and domains specified in federal legislation. As to psychometric properties, the test exhibits good to excellent reliability with split-half reliabilities of .86 and .93. Confirmatory factor-analytic models have supported construct validity, and concurrent validity support is provided by correlations of the test with other established achievement tests including the Kaufman Test of Educational Achievement and the Wechsler Individual Achievement Test (Schrank, McGrew, & Woodcock, 2001).

Primary Explanatory Measure.
Extent of academic supports in the school of the student was the sum of supports related specifically to academics and academic future preparation, and those potentially considered to have a significant

influence on mathematics achievement. The SEELS Wave 2 School Characteristics Questionnaire contained questions as to whether or not the school has services, resources, or programs available to students as either part of the curriculum or before/after school hours. The questions considered asked about (a) academic supports such as homework club, tutoring, or mentoring assistance; (b) diagnostic/prescriptive services provided by professionals to identify learning problems/plans programs; (c) college/ career awareness and preparation activities; (d) supplemental instructional services in reading/language arts; (e) supplemental instructional services in math. Academic supports total ranged from 0 to 5 with M=3.36, SD=1.38.

Contextual, Moderator, and Control Variables
These included cognitive disability, gender, family socioeconomic status, and grade level.

> *Cognitive disability.* Students with cognitive disabilities were expected to have lower performance on mathematics achievement and thus moderate the relationship between mathematics achievement and extent of academic supports. An indicator for presence of a cognitive disability was created based on whether the student had mental retardation, autism, traumatic brain injury, or multiple disabilities as reported by the teacher or by the parent if the teacher report was missing.

> *Gender.* An overview of the SEELS data from Wave I reported that girls did not performed as well as boys on a mathematics assessment (Blackorby, Chorost, Garza, & Guzman, 2003). Therefore an indicator for gender was included to investigate this factor as a possible moderator in the analyses.

> *Family socioeconomic status.* Family SES was considered an important control factor. A factorial index was formed from family income, parent or guardian's highest education level, and a poverty indicator, and was mean-centered.

> *Grade level.* Each wave of assessments was made across a wide range of grade levels (e.g., grades 1 to 9 at Wave 1). Because math achievement is clearly related to grade level, we included a mean-centered variable for grade level to control for this source of variability.

Sample Characteristics
The sample for the final analysis (N=292) was mostly male (59%). In terms of race/ethnicity, 56.6% were White, 26.4% African American, 12.3% Hispanic, 2.7% Asian American/Pacific Islander, and the remaining percentage was Native American and other/multi-racial. Students' grade in school ranged from 1st (2.7%) to 9th (0.3%) with fairly even percentages distributed across 2nd to 8th grades. As related to SES, household income was over $50,000 for 35.3%, and $25,000 and under for 38.2%. Parent/guardian's highest level of education was less than high school for approximately 10%, high school graduate 32%, some college 30%, and Bachelors or higher for 28%. The indicator for family in poverty was at 21%. All students had a visual impairment, either as designated by having VI as their primary disability (71.9%) or as identified by a parent or teacher as having a visual impairment (28.1%). Based on teacher or parent reports as defined above, 20% had a cognitive disability in addition to their visual impairment, and 9.3% were reported by parents as having complete blindness.

Analysis Procedure
Given the longitudinal nature of the data, we used multilevel modeling (or *growth curve analysis*). Multilevel modeling has advantages in data use efficiency, analytic flexibility, and variance parsing (cf. Hedeker & Gibbons, 2006; Tabachnick & Fidell, 2007). Multilevel modeling can use all available data (even if available at only one time point), can allow flexibility in the time between measurements, and can isolate subject variability in initial level (intercept) and in growth/change over time (slope) separate from residual error (Raudenbush & Bryk, 2002).
Longitudinal data involve repeated observations nested within participants. Multilevel modeling for this context employs models at two levels. The Level-1 model describes the growth trajectory for a given individual as a function of an intercept, slope multiplied by time, and a time-specific, and within-person error term. The Level-2 model allows for the intercept and the slope at level 1 each to be modeled further as a constant (average) plus individual (between-subjects) random deviation.

Data were converted from the initial *wide* layout, in which each row contains all data from a particular case, to a *long* or *person-period* dataset, in which each row contains data associated with each occasion

of measurement (observation wave). A variable, *Time*, was created in the person-period data file indicating the occasion of measurement for each observation: 0, 1, and 3 for waves 1, 2, and 3, thus allowing for the two-year interval between waves 2 and 3. PASW Statistics 17.0 was used for analyses, and the multilevel analyses employed the MIXED procedure with maximum likelihood (ML) estimation.

The analysis objective was to fit a linear growth model with random intercept and slope (e.g., Singer & Willett, 2003, pp. 75-137). We followed the procedural sequence recommended by Singer and Willett and others. An unconditional means model and an unconditional growth model were examined first, and these considered time as both fixed and random. Given significant unexplained residual variance (as was found), a sequential variable entry strategy was employed. The focal explanatory variable and interaction with time were entered next, then the same for the control variables, and, finally, interactions between academic supports and moderators (cognitive disability, gender, family SES). Terms not significant at the .05 level were removed to form the final model—with some exceptions deemed of special substantive interest.

Results
Sequential models. Both the unconditional means and the unconditional growth model (with Time as the only *predictor*) indicated significant remaining variance which potentially could be explained by additional predictors. Next, a conditional growth model was developed following the sequential model-building strategy previously described, beginning with inclusion of the main IV (academic supports total) and subsequently including moderator and control variables and interactions, all entered as level-2 (e.g., person-level) covariates. Except for selected cross-level interactions involving Time, nonsignificant interaction terms were not retained in the final model shown in Table 1.

Table 1. Longitudinal Covariate Model Parameter Estimates Predicting Math Achievement Over Time From School Academic Supports and Cognitive Disability, Controlling for Grade Level

Estimates of Fixed Effects

Parameter	Estimate	SE	df	t	p	95% Confidence Interval Lower Bound	Upper Bound
Intercept	489.07	5.60	376.37	87.39	0.000	478.07	500.07
Time	4.13	1.55	375.61	2.67	0.008	1.09	7.18
Grade	8.93	1.01	398.74	8.82	0.000	6.94	10.92
CogDis	-21.87	10.95	347.93	-2.00	0.047	-43.41	-0.33
AcSupTot	1.71	1.53	375.92	1.12	0.264	-1.30	4.72
CogDis * AcSupTot	-6.17	3.07	357.61	-2.01	0.045	-12.20	-0.14
Time * Grade	-1.48	0.29	379.14	-5.18	0.000	-2.04	-0.92
Time * CogDis	0.15	2.86	367.45	0.05	0.958	-5.47	5.77
Time * AcSupTot	0.32	0.42	374.95	0.77	0.444	-0.51	1.15
Time * CogDis * AcSupTot	0.10	0.82	371.71	0.12	0.906	-1.52	1.72

Note. CogDis = Cognitive Disability; AcSupTot = Academic Supports Total; Grade = Grade Level (mean centered).

Gender and family SES. Contrary to expectations, no gender effects of any kind (initial level, interactions, or effects over time) were detected, and the terms did not even approach conventional significance levels (smallest *p* = .403). Likewise, the index of family SES showed no effects of any kind (*p* ≥ .304) and thus was excluded because it was not a useful control variable.
Longitudinal covariate model estimates for fixed effects. In Table 1, *Intercept* indicated an average initial mean level Applied Problems score of 489. (Note that italicized terms in text refer to parameter estimates for corresponding terms in Table 1.) The *CogDis* term indicated a reduction (*p* = .047) of approximately 22 points at initial level for those students with a cognitive disability. There was no overall effect of level of school academic supports (*AcSupTot*) on initial level, but there was a significant interaction (*p* = .045) between presence of a cognitive disability and academic supports (*CogDis * AcSupTot*) on initial level score. (We will explore this interaction in more detail subsequently.)

The estimate for *Time*, the average initial growth rate (slope), indicated a significant 4.1-point increase (growth rate) per year in average Applied Problems scores. The lack of significant cross-level interactions with time and the focal predictors (*Time * CogDis, Time * AcSupTot, Time * CogDis * AcSupTot*) indicated no evidence that the average growth in achievement score differs among subgroups of students depending on cognitive disability and level of school academic supports.

Grade level (*Grade*) was included solely as a control for variability in scores associated with students being at different grade levels at each measurement wave. The significant positive estimate (8.9, *p* < .001) indicates that initial level mathematics scores increase 8.9 points per grade level, and that this variability was accounted for in the model. The significant negative estimate for the interaction with time (*Time * Grade*) indicated that the growth rate in the Applied Problems score is reduced by about 1.5 points per year, presumably because the mathematics curriculum becomes more difficult at higher grade levels. Again, the effect of this factor on growth, though not of direct substantive interest, was accounted for in the mode.

Variance parameters. All models that included predictors in addition to time (conditional models) showed a nonsignificant variance estimate for random slope. Consequently, all conditional models, including the final model, were exclusively random-intercept models. Thus, we controlled for student variability in initial level, but there was not enough variability in growth rate due to students to warrant inclusion of a variance parameter for this effect.

School academic supports and cognitive disability. This interaction and growth over time are shown graphically in Figure 1. The levels of school academic support were collapsed into quartiles for purposes of graphing and follow-up testing of the interaction. (Students in schools with 0, 1, or 2 supports formed the first quartile; the other total support levels [3, 4, 5] formed the second, third, and fourth quartiles, respectively.)

Comparison of the panels in Figure 1 clearly shows the significant higher initial level of scores for students without a cognitive disability. In addition, we observe mostly parallel lines for growth in scores over time. This illustrates the obtained lack of significant interactions with time for cognitive disability, academic supports total, and the interaction both of those factors with time.

With respect to the level of academic supports for those *without* a cognitive disability, there appears to be a pattern at initial level (time zero, Wave 1) such that students in schools with the maximum number of academic supports (fourth quartile) have higher scores than those in schools with fewer academic supports. This possibility (and the obtained interaction) was investigated by testing simple effects level of academic supports at each level of cognitive disability. The omnibus test for differences in initial-level scores by different levels of academic supports for students with no cognitive disability was significant (*p* = .041). Pairwise comparisons confirmed the pattern that scores were significantly higher for the forth quartile group vs. each of the other groups (*p*s ≤ .01). The parallel omnibus test by different levels of academic supports for students with a cognitive disability was not significant (*p* = .382), so no further pairwise testing was warranted. Similar testing at subsequent time points (times 1 and 3) showed the same patterns, thus further confirming our lack of significant interactions with time, as previously noted.

In summary, Figure 1 shows higher scores for those without a cognitive disability and, within that same group, higher scores for students in schools with the highest number of academic supports. For students with a cognitive disability, scores are lower overall, and there is no significant relationship between level of academic supports in the school and Applied Problems score. Finally, there is overall growth in achievement scores over time, and patterns of differences are maintained over the three measurement waves.
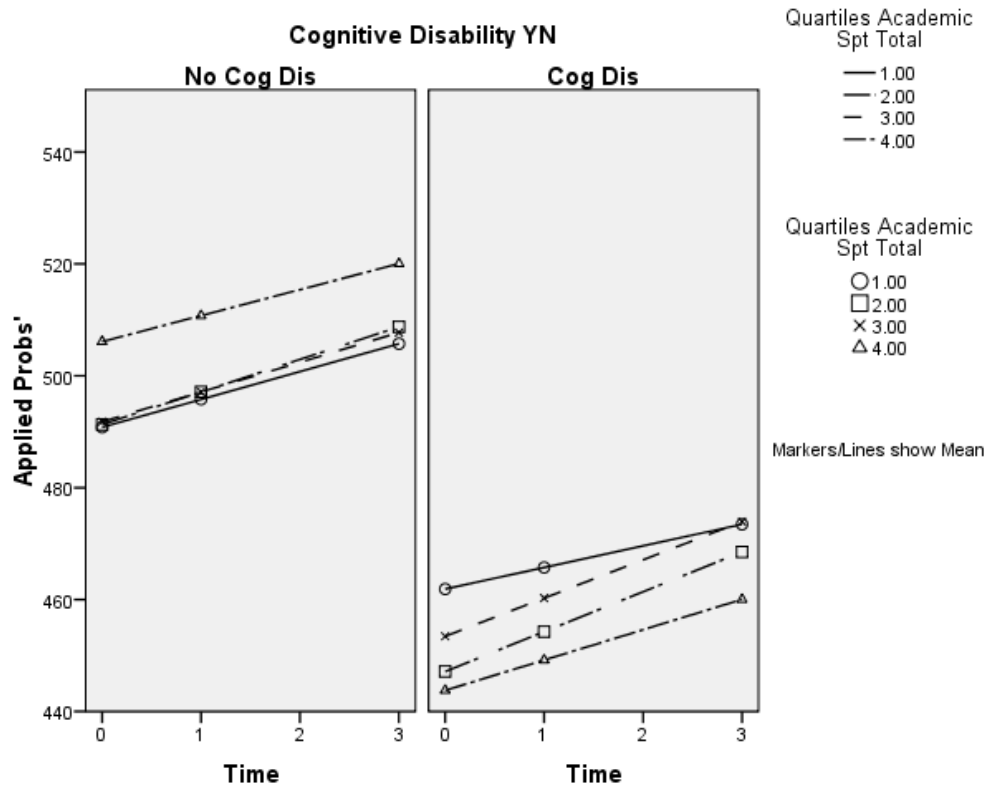
Figure 1. Mean Applied Problems scores over time by level of school academic supports (in quartiles) and by presence of a cognitive disability.

Discussion

The general context for this study involved mathematics achievement for VI students and the general lack of evidence regarding factors affecting the mathematics learning process for these students. We noted the special instructional needs of VI students and that their success was expected when such needs were met and appropriate supports were made available.

We focused on the school environment, specifically the extent of academic supports in the school and its relationship to mathematics achievement of VI students. Our expectations for outcomes were based on findings for nondisabled students in the same context, as no empirical evidence for VI students was previously available.

Extent of Academic Supports in the School

Regarding our first research question, we did not find a simple overall relationship between extent of academic support in the school and mathematics achievement for either initial level or growth in achievement over time. Instead the relationship was more complex. Per our second research question, we did find that the presence of a cognitive disability moderates a relationship between the extent of school support and mathematics achievement. This relationship appears to occur only for VI students without a cognitive disability. The extent of academic support in the school appears to be positively related to mathematics achievement for VI students without a cognitive disability. This finding is consistent with studies identifying academic supports as a critical characteristic of effective schools (Kitchen, DePree, Celedón-Pattichis, & Brinkerhoff, 2004) and a major strategy that schools can implement to improve academic standards (General Accounting Office, 2009). Thus, these broad, general findings for nondisabled students in the area of mathematics learning can be extended specifically to students who are visually impaired.

In addition, our finding of higher math achievement for students in schools with the highest level of academic supports (see left panel of Figure 1) is consistent with a threshold concept. It may be that there

is a threshold or critical mass in terms of the number of academic supports in the school that serve to identify schools with an academic support environment strong and extensive enough that these schools can enhance mathematics learning for VI students without a cognitive disability.

Cognitive Disability
We did not detect any relationship between extent of school supports and mathematics achievement for students with a cognitive disability. There may be multiple reasons for failure to find a relationship here. First, in addition to the interaction with extent of school supports, presence of a cognitive disability had—by far—the largest overall effect (was associated with the most decline) on initial achievement scores. Our classification of students with a cognitive disability included mental retardation, autism, traumatic brain injury, or multiple disabilities in addition to visual impairment. Nondisabled students with such cognitive-related disabilities are generally known to show lower levels of mathematics and other academic achievement. The cognitive disability classification is a mixed group, thus having more varied support needs. Such varied needs could lead to more variation in achievement, which, in turn, could make relationships with school supports more difficult to detect. Another possibility is that VI students with a cognitive disability have a high level of need for specialized supports (beyond available academic supports), possibly involving a specialized Teacher of the Visually Impaired (TVI). This need situation may make detection of any relationship with school supports considerably more difficult. In addition, VI and cognitive disability in combination may produce a more complex need situation in which the extent of school supports is a factor of lesser importance in student achievement.

Concerning growth, it is encouraging that we did not find evidence of slowed growth in achievement over time for VI students with a cognitive disability. Though they are at a lower level of mathematics achievement, we did not find evidence that those with a cognitive disability were falling farther behind in achievement.

Gender and Family SES
No hint of a gender effect or moderation on initial level or growth in mathematics achievement is apparent for VI students with or without a cognitive disability. This finding is consistent with contemporary research on mathematics achievement for nondisabled students (cf. Hyde, Lindberg, Linn, Ellis, & Williams 2008).
Likewise, we found no direct effect of family SES (or moderation effect) on mathematics achievement for VI students with or without a cognitive disability. Additional analyses revealed that family SES had a substantial correlation with school SES (as indexed by percent of students in the school eligible for free or reduced price lunch). Similarly, additional analyses showed no effect of any kind for school SES.

Limitations and Conclusions
Although the longitudinal nature of our data from SEELS is a design strength, and our multilevel modeling approach maximized information use and control for extraneous variances, the analysis is essentially correlational in nature. We have sometimes referred to *effects*, but these are most accurately described as relationships. Although SEELS is a very rich dataset, with a very large number and diversity of measures, the measures ideal for an investigator's research focus may not be available or, if available, may not be as extensive as desired. Such was the case in this study for measures of school academic supports. A further limitation is the difficulty surrounding investigation of a relationship across measurement context levels: the extent of academic supports in the school (school level) as related to student mathematics achievement (student level). Further research will be needed to investigate mechanisms by which school factors can affect student outcomes.

Our final conclusions point to an effect such that higher levels of academic supports in the school have the most influence on mathematics achievement for students who are visually impaired and who do not have a cognitive disability. There may be a threshold level for number of supports in the school to identify those schools in which VI students are most likely to excel. The presence of a cognitive disability in addition to visual impairment is critically important to consider. Students with such a combination of disabilities most likely will need specialized supports, provided with the involvement of specialists, such as teachers of the visually impaired (TVIs), to have the best chance to excel in mathematics learning. Finally, it is encouraging that we did not detect declines in the growth of mathematics achievement for either those VI students who have or do not have a cognitive disability.

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