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Five-Year Growth Trajectories of Kindergarten Children With Learning Difficulties in Mathematics

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The investigators used data from the *Early Childhood Longitudinal Study–Kindergarten Cohort* (ECLS-K) to estimate whether and to what extent the timing and persistence of mathematics difficulties (MD) in kindergarten predicted children's first through fifth grade math growth trajectories. Results indicated that children persistently displaying MD (i.e., those experiencing MD in both fall and spring of kindergarten) had the lowest subsequent growth rates, children with MD in spring only had the second-lowest growth rates, and children with MD in the fall only (and who had thus recovered from their MD by the spring of kindergarten) had the next-lowest growth rates. The children who did not have MD in either fall or spring of kindergarten had the highest growth rates. These results were observed prior to and after statistical control for additional variables. They indicate that measuring the timing and persistence of kindergarten children's mathematics learning difficulties may help identify those most at risk for failing to become mathematically proficient during elementary school.

Keywords: *mathematics difficulties; reading difficulties; mathematics disabilities; learning disabilities; mathematics achievement; kindergarten; longitudinal*

The failure to become proficient in mathematics is a major obstacle to societal opportunity. For example, being poorly skilled in mathematics lowers an adult's employability and wages over and above poor reading skill, low IQ, and many other factors (Rivera-Batiz, 1992). Even adults who are skilled readers are more likely to be unemployed (and less likely to be promoted when employed) if they are not skilled in mathematics (Parsons & Bynner, 1997). Because of its importance to both individuals and society as a whole, policy makers now mandate that all U.S. schoolchildren graduate as mathematically proficient (Public Law 107-110, the No Child Left Behind Act of 2001).

However, researchers and practitioners have only limited knowledge about the onset, trajectories, and risk factors for learning difficulties in mathematics. This is particularly the case during the early school years (Gersten, Jordan, & Flojo, 2005). For example, few investigations have been longitudinal (Chong & Siegel, 2008; Guarino, Hamilton, Lockwood, & Rathburn, 2006). Fewer still have evaluated which of a range of factors elevate a child's risk of mathematics difficulties (MD; e.g., Jordan, Kaplan, Locuniak, & Ramineni, 2007). Yet such studies were critical in increasing the field's understanding of the instructional needs of children with reading difficulties and disabilities (e.g., Bus & van IJzendoorn, 1999; Juel, 1988; National Institute of Child Health and Human Development, 2000). It is reasonable to suppose that investigating the early occurrence, trajectories, and predictors of children's mathematics learning should inform efforts to help all children become mathematically proficient.

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Theoretical Accounts of Children's Mathematics Skills Growth

There are contrasting views of the process by which children become increasingly proficient in mathematics (Aunola, Leskinen, Lerkkanen, & Nurmi, 2004). One possibility might be characterized as a cumulative growth model. Here, children (through ongoing interactions with teachers, parents, siblings, peers, and others) continually refine and extend their earlier understandings about mathematics. These earlier understandings should come about through informal instructional interactions (e.g., helping the child learn to count, teaching the child the meaning of "third") provided during the children's preschool years (Baroody, Lai, & Mix, 2006). Those children entering kindergarten with more mathematical knowledge keep adding to this knowledge and so become increasingly skilled over time. Those children entering kindergarten with less knowledge also continue to learn more about mathematics but at a relatively slower rate. Thus, children experiencing the early onset of MD should continue to display MD as they move through elementary school.

A second possibility might be characterized as a lag model (Aunola et al., 2004). Here, children entering kindergarten at lower levels of mathematics knowledge and skill tend to increase this knowledge and skill more rapidly than those who enter school at higher levels. As a consequence, lower skilled children begin to catch up to their higher skilled peers. This occurs as lower skilled children begin to receive systematic instruction in school, which helps overcome any learning disadvantages these children may have experienced prior to school entry (Phillips, Norris, Osmond, & Maynard, 2002). Thus, and over time, the magnitude of the skills gap between lower and higher skilled children should decrease rather than remain constant or increase (Aunola et al., 2004; Jordan, Kaplan, Olah, & Locuniak, 2006). Children experiencing the early onset of MD may, therefore, no longer display MD as they grow older.

Empirical evidence for either type of dynamic is limited (Mazzocco & Myers, 2003). This is because relatively few studies have directly estimated young children's growth trajectories in mathematics. One such study (i.e., Aunola et al., 2004) measured the mathematics skills of 194 children from preschool to second grade. Their analyses showed a high degree of stability in children's mathematical proficiency. These results, as well as those reported by Chong and Siegel (2008), Muthen and Khoo (1998), and Williamson, Appelbaum, and Epanchin (1991), support a cumulative growth model. In contrast, Jordan et al.'s (2006) analyses indicated that some children entering kindergarten with relatively low skills display moderate or rapid skills growth in mathematics over the school year. Their results provide some support for a lag model.

Characteristics of Mathematics Difficulties and Disabilities

MD constitute low performance in mathematics (Gersten et al., 2005). Typically, researchers have identified children as having MD if they scored in the bottom 25% to 30% on a single measure of mathematics knowledge (e.g., Fuchs, Fuchs, & Prentice, 2004; Geary, Hoard, & Hamson, 1999; Hanich, Jordan, Kaplan, & Dick, 2001; Jordan, Hanich, & Kaplan, 2003; McLean & Hitch, 1999; White, Moffitt, & Silva, 1992; Wilson & Swanson, 2001). Yet the resulting group of children identified as MD likely remains heterogeneous. This is because the children's low skill level may result from distinct mechanisms. Some children may perform poorly because their learning disabilities consistently interfere with their attempt to learn mathematics. Other children may display less skill due to, for example, their family's economic disadvantage (Denton & West, 2002; Jordan et al., 2006). Being raised in home environments that provided fewer opportunities to informally learn about mathematics should delay these children's skills acquisition until after school entry (Starkey, Klein, & Wakeley, 2004).

Exclusionary criteria and a discrepancy formula have traditionally been used to differentiate children with mathematics disabilities from those displaying low skill levels for reasons attributable to economic disadvantage or other factors. A child whose mathematics achievement was substantially below what would be expected given the child's IQ would therefore likely have a mathematics disability. However, use of a discrepancy for disability identification is increasingly considered untenable (Fletcher et al., 1998; Siegel, 1989). Yet, and unlike for reading disabilities, a set of "core deficits" constituting mathematics disabilities remains to be identified (Mazzocco & Myers, 2003). Researchers have therefore sought to identify those children with mathematics disabilities on the basis of additional performance criteria. One frequently used criterion is a more restrictive cutoff (e.g., 10% vs. 30%) score (e.g., Chong & Siegel, 2008). A 10% cutoff is considered to be more consistent with reported prevalence rates of mathematics disabilities (Geary, 2004; Shalev, Auerbach, Manor, & Gross-Tsur, 2000).

Another criterion is that a child display persistent difficulties in mathematics. That is, the child is more likely to have a mathematics disability if he or she repeatedly scores poorly on a measure of mathematics knowledge rather than scoring poorly at a single time point (Geary et al., 1999). As with a more restrictive cutoff score, a persistency criterion is considered to be more consistent with mathematics disabilities prevalence rates (Mazzocco & Myers, 2003). Furthermore, a persistency criterion is more in keeping with identification methods that attempt to rule out lack of access to adequate instruction as a reason for a child's poor performance (Fuchs, 2006).

However, the predictive utility of a persistency criterion has yet to be well established. A few studies (e.g., Geary, Hamson, & Hoard, 2000; Mazzocco & Myers, 2003) have systematically contrasted young children displaying repeated difficulties in mathematics with those not displaying such repeated difficulties. These studies have yielded important findings. Yet these studies have relied on small samples and relatively short longitudinal time frames. To our knowledge, no study has contrasted the growth trajectories of kindergarten children repeatedly displaying MD with those displaying more variable types of MD or with non-MD peers as these children move through elementary school, while also controlling for the effects of a wide range of potentially confounding factors. Yet such analyses have the capacity to substantially inform early screening and intervention efforts, as well as to provide much needed empirical evidence for the process by which children attain proficiency in mathematics. We more fully detail the rationale for these analyses below.

Risk Factors for Mathematics Difficulties

Relatively few investigations have identified factors that can elevate a child's risk of MD. For instance, Jordan et al. (2007) reported that children from low-income households were more likely to display poor mathematics skills. Both Aunola et al. (2004) and Jordan et al. (2006) found that girls were less likely to be highly skilled in mathematics than boys. Others identified risk factors include entering kindergarten at a younger age, being a poor reader, or being inattentive (e.g., Cirino, Fletcher, Ewing-Cobbs, Barnes, & Fuchs, 2007; Fuchs et al., 2006; Jordan et al., 2007; McClelland, Acock, & Morrison, 2006; Miller & Mercer, 1997).

Such investigations have yielded some contradictory results. For example, Mazzocco and Thompson (2005) found that children living in low-income communities were no more likely to be identified as having mathematics disabilities than children living in high-income communities. Lachance and Mazzocco's (2006) analyses indicated that sex differences between young children on standardized measures of mathematics skill were "minimal or nonexistent" (p. 210). Although Jordan, Hanich, and Kaplan (2003) reported that children who were retained learned mathematics at about the same rate as children who were not retained, Hong and Raudenbush (2005) estimated that being retained lowered at-risk children's mathematics knowledge by about two thirds of a standard deviation, whereas Jimerson's (2001) meta-analyses estimated an overall effect size of –.43 for retention of such knowledge.

Methodological limitations may be contributing to these contradictory findings. For instance, few studies have directly investigated the effects of a child's socioeconomic status (SES) on his or her mathematics learning by using a measure of parent- or guardian-reported education and income. Instead, the effects of SES have typically been measured indirectly (and thus less accurately) using school reports of whether the child was eligible for free or reduced lunch (e.g., Jordan et al., 2003) or census variables associated with a school's ZIP code (Lachance & Mazzocco, 2006). Dichotomization of SES (low income vs. not low income) may yield less precise estimates of its effects (Cohen, Cohen, West, & Aiken, 2003). None of the prior studies have analyzed data from a large, nationally representative sample of children. Instead, prior studies have relied on small convenience samples of children attending a particular subset of schools or school districts, with study samples sometimes restricted to low-performing children in these schools and districts (e.g., Cirino et al., 2007; Fuchs et al., 2006; Jordan et al., 2007; Mazzocco & Thompson, 2005). Reliance on such samples may limit the identification of particular subgroups of children (e.g., those with disabilities) most in need of early intervention (Bennett, Lipman, Racine, & Offord, 1998; Campbell, Shaw, & Gilliom, 2000). Use of larger, more nationally representative samples should provide more accurate estimates of a given risk factor's effects for the population of U.S. schoolchildren as a whole. In addition, prior studies have often tracked children's skills growth over a single school year or a few years rather than over the length of children's time in the elementary grades (e.g., Aunola et al., 2004; Diperna, Lei, & Reid, 2007; Jordan et al., 2003; Jordan et al., 2007; Mazzocco & Thompson, 2005).

Substantive limitations also characterize the literature. For example, most studies estimating risk factors have reported on the effects of characteristics that cannot be targeted for intervention by school staff (e.g., the child's gender or race/ethnicity). Relatively few studies have estimated the effect of factors that might be considered "educationally relevant," as these factors might be targeted in multicomponent interventions designed to increase children's mathematical proficiency. Examples of such "learner characteristic" (Chard et al., 2008) factors include the child's relative reading skill and the frequency with which he or she engages in behaviors that facilitate learning (e.g., being attentive, persistent, and organized) while working on classroom tasks. Each factor predicts children's learning of mathematics (e.g., Diperna et al., 2007; Duncan et al., 2007; Fuchs et al., 2006; Jordan et al., 2007). In addition, the extent to which young children diagnosed with disabilities may be at elevated risk of failing to become mathematically proficient remains to be established. Existing estimates of these children's risk (e.g., National Assessment of Educational Progress [NAEP], 2005) may be biased, as they fail to account for confounding factors such as SES, retention, reading proficiency, and frequency of learning-related behaviors. A child's disability is also an educationally relevant factor, in that educators may need to make specific adaptations to their mathematics instruction to better meet the child's special learning needs (e.g., Bryant, Kim, Hartman, & Bryant, 2006). The predictive utility of these more educationally relevant factors should be investigated because they may play a role in a child's response to instruction and may also be amenable to intervention (Chard et al.).

Study's Rationale and Purpose

We attempted to identify predictors of kindergarten children's initial knowledge of mathematics and rates of mathematics skills growth over time. We were particularly interested in categorizing the persistence of early mathematics learning difficulties and then estimating the predictive utility of such categorization on children's subsequent growth trajectories in mathematics. We did so based on the observation that two types of early experiences should affect the mathematical proficiency of children entering first grade. The first type of experience, as noted above, occurs during the child's preschool years, with the child's response to this more informal instruction (whether delivered in a day care setting, in a Head Start classroom, or during interactions with a parent or sibling in the child's home) being indicated by his or her mathematical knowledge at the beginning of kindergarten. Those with relatively "richer" educational experiences prior to kindergarten should enter school as relatively more skilled in mathematics (Klibanoff, Levine, Huttenlocher, Vasilyeva, & Hedges, 2006). The second type of early experience occurs in kindergarten, with the child's response to more formal kindergarten instruction indicated by his or her skill level at the end of the kindergarten school year.

When the question of interest is evaluating the persistence of a kindergarten child's learning difficulties in mathematics, there are four possibilities. First, the child might have entered kindergarten displaying MD and continued to display MD at the end of the school year. Such low performance in preschool, combined with a failure to "catch up" in kindergarten, seems to indicate a more severe, persistent, or intransient variation of MD. Second, the child might have performed acceptably in preschool but displayed MD at the end of kindergarten. This seems likely to indicate a lesser but still strong type of MD. This child, relative to other children his or her age, is displaying substantially less proficiency in early mathematics skill just prior to receiving more intensive instruction in first grade. This early onset of MD would seem to elevate the child's risk for subsequent learning difficulties in mathematics. Third, the child might have displayed MD after his or her preschool years but responded adequately to more formal kindergarten instruction, so that MD is not present at the end of kindergarten. This is likely to be the weakest type of MD because the child is no longer displaying MD prior to the beginning of first grade instruction. Finally, those children who did not display MD during either preschool or kindergarten instruction can reasonably constitute a reference group of "non-MD" children, against whom the subsequent growth trajectories of those with MD can be measured. If the mathematics growth rates of these four groups of children are found to be ordered in the sequence just described, then this would provide empirical evidence supporting the theoretical view that an early and persistent onset of mathematics learning difficulties indeed matters (that is, these children are unlikely to "grow out of it") and so should be taken into account when identifying those needing more intensive instructional efforts.

In addition, we were interested in whether and to what extent a set of educationally relevant factors, such as whether the child was retained, his or her initial proficiency in reading, and the frequency with which he or she engaged in learning-related behaviors (e.g., remained attentive, persisted at tasks), predicted the child's mathematics learning, especially after statistically controlling for a child's sociodemographic characteristics, including social class background, race, age at school entry, and gender. Such estimates may help identify additional factors that might be targeted in early intervention efforts for children with MD. Moreover, and by controlling for both sociodemographic and these more educationally relevant factors, our analyses should provide for a rigorous investigation of the need to account for the timing and persistence of a kindergarten child's MD when deciding whether the child may require early intervention services in order to grow to become mathematically proficient.

Method

Study's Database

We used data from the *Early Childhood Longitudinal Study–Kindergarten Cohort* (ECLS-K). The ECLS-K is maintained by the U.S. Department of Education's National Center for Educational Statistics (NCES). NCES selected a nationally representative sample of kindergarteners in fall 1998. Data from participating children are currently available through spring 2004 (i.e., the end of fifth grade for most of the children). Sampled children attended both public and private kindergartens offering both full- and part-day programs. The original sample included 17,487 children attending about 3,500 classrooms in 1,280 schools. NCES used sample freshening to help make the ECLS-K nationally representative of all first graders in fall 1999. (However, we could not include these children in our study because they were not administered measures of their mathematical knowledge as kindergarteners.) Published data from children participating in the ECLS-K were collected in fall 1998, spring 1999, spring 2000 (with data collected on a randomly selected subsample in fall 1999), spring 2002, and spring 2004. For most children (e.g., those not retained in grade), these data collection points occurred during fall and spring of kindergarten and spring of first, third, and fifth grades.

Our analytical sample included those children whose parent-identified race or ethnicity was (a) White, non-Hispanic or (b) Black/African American, non-Hispanic. We excluded children of other racial or ethnic heritage because substantially larger numbers of these children had missing information from the kindergarten administration of the ECLS-K Reading Test. NCES field staff did not consider some of these children as sufficiently proficient in spoken English to have the test administered to them (see Note 1). Including only those racial or ethnic groups of children who had completed the Reading Test was necessary to estimate the effects of a child's reading proficiency on his or her learning of mathematics, as well as the effects of his or her race or ethnicity. Our analytical sample did include first-time and retained kindergarteners, as well as children who had changed and who had not changed schools between the study's six data collection points.

Measures

Mathematics skill. We used scores from the ECLS-K Mathematics Test to estimate a child's mathematics knowledge during fall and spring of kindergarten, as well as his or her skills growth over first, third, and fifth grades. The Mathematics Test seeks to measure a range of age- and grade-appropriate mathematics skills (e.g., identify numbers and shapes, sequence, add or subtract or multiply or divide, use rates and measurements, use fractions, calculate area and volume). NCES used a multistage panel review process to develop the ECLS-K's Mathematics Test (NCES, 2005). This test was based on the NAEP's specifications. A wide range of kindergarten-, first grade-, third grade-, and fifth grade-level mathematics test items was used.

NCES used item response theory (IRT) methods to generate adaptive tests that were administered one-to-one to each child in an untimed format. A child first took a brief routing test. A second test, which was matched based on a child's scores on the routing test, was then administered. NCES considers use of the IRT scores as the most appropriate metric for growth modeling, as these scores can be compared across different test form administrations and across different grades (NCES, 2006). Reliabilities of the IRT scaled scores ranged from .89 to .94 across all of the study's six points (NCES). High correlations (i.e., third grade = .84, fifth grade = .80) between the Mathematics Test's IRT scores and children's scores from the *Woodcock-McGrew-Werder Mini-Battery of Achievement* (Woodcock, McGrew, & Werder, 1994) support its concurrent validity.

Reading skill. We predicted a child's initial level of mathematics knowledge and subsequent rate of skills growth by the child's initial (i.e., during fall of kindergarten) level of skill in reading. We did so by using children's scores from the ECLS-K Reading Test. This test seeks to measure children's basic skills (e.g., print familiarity, letter recognition, decoding, sight word recognition), vocabulary (receptive vocabulary), and comprehension (i.e., making interpretations, using personal background knowledge). The Reading Test was constructed through a multistage panel review. Some items were borrowed or adapted from published tests (e.g., the *Peabody Picture Vocabulary Test–Revised*, the *Woodcock-Johnson Tests of Achievement–Revised*). The Educational Testing Service, elementary school curriculum specialists, and practicing teachers supplied other items. All items were field tested. Items were included in the test's final form if they displayed (a) acceptable item-level statistics, (b) good fit with maximum likelihood IRT parameters, and (c) no differential item functioning across gender or race (NCES, 2005). The fall of kindergarten reading IRT score has a reliability coefficient of .91 (NCES, 2006). We considered those children whose scores were in the bottom 10% of the fall of kindergarten administration of the Reading Test as displaying reading difficulties. Use of a 10% cutoff is consistent with previous empirical work on the prevalence of clinically significant reading problems (Catts, Fey, Zhang, & Tomblin, 2001; Konold, Juel, & McKinnon, 1999).

Learning-related behaviors. We predicted a child's initial knowledge of mathematics and skills growth over time using the frequency with which he or she engaged in learning-related behaviors during the fall of kindergarten. We measured a child's learning-related behaviors using teacher rating on the ECLS-K modified version of the *Social Skills Rating System* (Gresham & Elliott, 1990), Approaches to Learning subscale. (NCES refers to this modified version of the *Social Skills Rating System* as the *Social Rating Scale*.) The Approaches to Learning subscale's six items seek to measure a child's attentiveness, task persistence, eagerness to learn, learning independence, adaptability to changes in routine, and organization. Learning-related behaviors are considered distinct from other behaviors such as socioemotional or interpersonal skills (McClelland & Morrison, 2003) and have previously been identified as strong predictors of children's mathematics learning (Duncan et al., 2007; McClelland et al., 2006). The fall of kindergarten split half reliability for the subscale was .89 (NCES, 2006). We considered those children who were rated by teachers to be in the bottom 10% of the fall of kindergarten administration of the Approaches to Learning subscale as infrequently displaying learning-related behaviors. A 10% cutoff is consistent with the prevalence rates for clinically significant behavior problems (Feil et al., 2005; Roberts, Attkisson, & Rosenblatt, 1998).

Age, SES, race, gender, and kindergarten retention. We analyzed to what extent a child's age in kindergarten, SES, race, gender, or kindergarten grade retention predicted his or her initial skill level and rate of skills growth over time in mathematics. Data on these factors were collected during the fall of kindergarten. The continuous age variable indicated a child's age in months at the start of fall kindergarten (i.e., September 1998). The SES variable measured a household's SES by the spring of kindergarten. NCES calculates a household's SES using information about a father's (or male guardian's) and mother's (or female guardian's) education and occupation as well as the family's household income. NCES estimates SES using both a continuous and a categorical scale. We used the continuous variable (i.e., WKSESL). This variable ranged from –4.75 to 2.75. The dichotomous race variable indicated whether the child was parent-identified as White, non-Hispanic or Black/African American, non-Hispanic. We also used a dichotomous variable indicating whether the child repeated kindergarten or not. Doing so was necessary so that our estimate of the age effect was not confounded by whether the child was older because he or she had repeated kindergarten. We also were able to provide a separate estimate of retention's effects on children's learning of mathematics.

Disability status. We used a dichotomous variable indicating whether a child had an Individualized Education Plan (IEP) on record at school by the spring of kindergarten. A school's administrative records are frequently used as an indicator of a child's disability status (e.g., Hollomon, Dobbins, & Scott, 1998; Hosp & Reschly, 2002). We used the IEP variable to indicate whether the child had been formally identified as having a disability. The majority (i.e., 78%) of children with IEPs participating in our study's analytical sample had been identified as having learning disabilities or speech or language impairments.

Missing Data

Our initially defined sample included 12,385 children. However, we excluded from subsequent analysis those children who had missing data on any child-level predictor (e.g., race, gender, retention) or the Mathematics Test at the fall and spring of kindergarten time points (which we used for creating dummy variables indicating whether children had MD). However, we did not exclude from analysis those children who had missing scores on the Mathematics Test at spring of first, third, and fifth grades unless they had missing scores on all three time points. This is because our growth analysis, which was estimated using Hierarchical Linear Modeling (HLM; Raudenbush & Bryk, 2002), allows for the inclusion of any child who had such missing data (see Analytical Strategy section for additional detail). Our final analytical

Table 1
Demographic Characteristics for the *Early Childhood Longitudinal Study–Kindergarten Cohort*'s (ECLS-K) Full and Analytical Samples

Characteristic	Full Sample (N = 12,385)	Analytical Sample (N = 7,892)
Gender		
Male	51.22%	50.85%
Female	48.78%	49.15%
Race		
White	79.86%	82.68%
Black or African American	20.14%	17.32%
IEP		
Yes	6.99%	6.37%
No	93.01%	93.63%
SES[a]	.12 (.78)	.14 (.77)
Fall kindergarten Mathematics Test IRT score	23.93 (8.91)	24.31 (9.00)

Note: Standard deviations are in parentheses. IEP = Individualized Education Plan; SES = socioeconomic status; IRT = item response theory.
a. Using WKSESL.

sample included 7,892 children. Table 1's descriptive statistics indicate that those children in the full and analytical samples were highly similar on a range of sociodemographic (i.e., gender, race, SES) and additional (i.e., disability status, fall of kindergarten Mathematics Test score) factors.

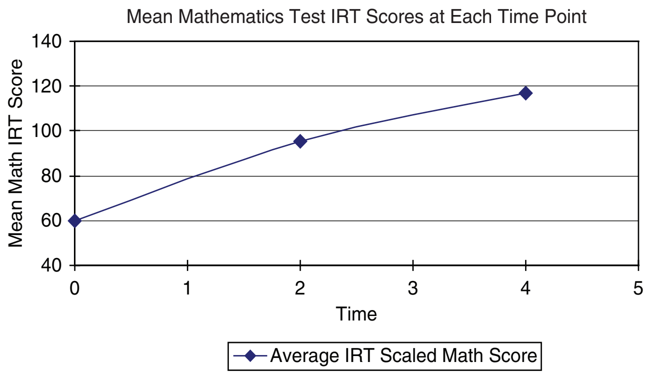
Analytical Strategy

Mathematics difficulties. We used a child's fall and spring of kindergarten mathematics scores to create a set of dummy variables indicating a child's status of MD. We first created two dummy variables (Difficulties, or "D," at Times 1 and 2) indicating whether the child had scored in the bottom 10% on the fall and/or spring administrations of the Mathematics Test, based on the scores of the full sample of kindergarten children who were White and non-Hispanic or Black. We then created three analytical dummy variables. If the child scored in the bottom 10% at both time points, then D11 was set to 1; otherwise, D11 was set to 0. If the child scored in the bottom 10% in fall of kindergarten, but not in spring, then D10 was set to 1; otherwise, D10 was set to 0. If the child scored in the bottom 10% in spring of kindergarten, but not in fall, then D01 was set to 1; otherwise, D01 was set to 0. As a consequence, those who did not score in the bottom 10% in either fall or spring of kindergarten were used as a non-MD reference group. We also sought to estimate the effects of a kindergarten child's sociodemographic characteristics, grade retention, reading proficiency, frequency of learning-related behaviors, and disability status on his or her initial skill level and skills growth over time in mathematics. Thus, we estimated the effects of D10, D01, and D11 on subsequent mathematics intercepts and growth rates both without and with controls for these covariates. We used a 10% cutoff to identify children as having MD. This cutoff is consistent with previously reported prevalence rates for mathematics disabilities and is considered a relatively conservative criterion (Geary, 2004; Mazzocco & Myers, 2003).

Time. Because the study's three time points (i.e., spring of first, third, and fifth grades) are equally spaced, we set the value of our first time point at 0 (indicating the child's relative level of mathematics knowledge at spring first grade) and then set values for the subsequent time points in relation to their relative distance from this first time point, with the addition of every 2 academic years associated with an increment of 1 in the time scale. This resulted in the values of 0, 1, and 2 for spring 2000, spring 2002, and spring 2004 test administrations, respectively.

Growth modeling. Both Structural Equation Modeling (SEM) and HLM can be used to model growth data. SEM-type growth modeling uses both initial status and growth as two latent factors, and the different observation points as indicators of both latent factors (Klein, 2005). Any predictors of factors are treated as covariates of the latent factors. HLM-type growth modeling uses the observations at varying time points as the first level of data nested within an individual, which is at the second level. The models estimating these two levels are also called the repeated-observations model and the person-level model in HLM (Raudenbush & Bryk, 2002). HLM may not be as flexible as SEM in terms of model specification. However, a key feature of HLM is that it does not require balanced "time-structured" data (Raudenbush & Bryk, 2002). That is, HLM allows the use of an available data point even if, say, data are unavailable on a particular child at the other observation points. Thus, we used HLM to conduct our analyses because many of the study's children did not have scores available from all data collection waves. Among the study's analytical sample of 7,892 children, 5,119 children had complete data at all three time points, 1,523 children had observations at two time points, and 1,250 children had observations at one time point . HLM 6 (Raudenbush, Bryk, Cheong, & Congdon, 2004) was used to conduct the analyses.

Figure 1
Mathematics Growth Trajectories, First Through Fifth Grades



We estimated a two-level model with the repeated observations over time being the first level and child the second level. Level 1's equation specified the score at each time point as a function of time. First, we plotted the mean mathematics scores at the three time points. Figure 1 indicates that the growth curves showed some leveling off at the last time point, suggesting the need for a quadratic growth curve. We therefore employed this functional form in the analyses.

The Level 1 equation is expressed as follows:

$$Y_{ti} = \pi_{0i} + \pi_{1i}t + \pi_{2i}t^2 + e_{ti} \tag{1}$$

for $I = 1, 2, 3, \ldots, n$ subjects, where t is the time and π_{0i} is the initial status of the child at Time 0, π_{1i} is the linear slope, indicating the instantaneous growth rate of person i at the initial time point (i.e., spring 2000 in our case), and π_{2i} is the quadratic curvature and represents the acceleration in each growth trajectory. The growth rate of person i at any particular time point is the first derivative of the growth model at that point, which is equal to $\pi_{1i} + \pi_{2i}t$ (Raudenbush & Bryk, 2002). This indicates that if π_{2i} is positive, the person is growing at an accelerating rate, and vice versa. The e_{ti} is the measurement error at the first level and is assumed to be normally distributed with a mean of 0 and constant variance.

In Level 2, the intercept and slope terms of the regression equation become the criterion variables and can be predicted by a set of child-level characteristics. The Level 2 equations (for the study's full set of predictors) for the initial status and growth rate parameters are as follows:

$$\begin{aligned}\pi_{0i} = {} & \beta_{00} + \beta_{01}(Age) + \beta_{02}(SES) + \beta_{03}(Race) + \beta_{04}(Gender) \\ & + \beta_{05}(repeating\_kindergarten) + \beta_{06}(reading) \\ & + \beta_{07}(approaches) + \beta_{08}(IEP) + r_{0i} \\ \pi_{1i} = {} & \beta_{10} + \beta_{11}(Age) + \beta_{12}(SES) + \beta_{13}(Race) + \beta_{14}(Gender) \\ & + \beta_{15}(repeating\_kindergarten) + \beta_{16}(reading) \\ & + \beta_{17}(approaches) + \beta_{18}(IEP) + r_{1i} \\ \pi_{2i} = {} & \beta_{20}\end{aligned} \tag{2}$$

where β estimates the effect of a predictor on a child's initial status and growth rate, and r_{0i} and r_{1i} are random error. The coefficient of the quadratic term was set to be invariant because three time points do not provide sufficient degrees of freedom to estimate the random effects of the quadratic term. All categorical predictors were uncentered, but the continuous predictors were grand-mean-centered in our analysis so that the intercept parameters (i.e., β_{00} and β_{01}) could be better interpreted. For example, for the model including the full set of predictors, the estimate for β_{00} can be interpreted as the estimated initial score for the average SES male non-MD child who is Black and of average age, who has an average Reading Test score and an average Approaches score, and who did not repeat kindergarten.

Predictor models. We used four models to estimate the effects of the study's full set of predictors on a child's initial and over time learning of mathematics. In the baseline model (i.e., Model 1), we included no predictors. This model is typically termed an unconditional model. The unconditional model allows us to estimate the reliability of the intercept and the linear slope parameters. Reliability estimates measure the ratio of the true parameter variance to the total observed variance. If the reliability estimates are too small, we may fail to find any systematic relation between person-level predictors and the growth parameters (Raudenbush & Bryk, 2002). In Model 2, we added the three dummy variables indicating whether the child scored in the bottom 10% in either the fall or spring kindergarten math test or both. In Model 3, we added to Model 2 a child's sociodemographic variables of age, SES, race, and gender as well as whether the child repeated kindergarten. In Model 4 (i.e., the model expressed in Equations 1 and 2), we added to Model 3 whether a child had been identified as disabled by the spring of kindergarten and whether the child displayed reading difficulty or infrequent learning-related behaviors in the fall of kindergarten. HLM 6 allows the user to specify weights at each level, and we used NCES-constructed child-level sampling weights

Table 2
Descriptive Statistics for the Analytical Sample of Children

Child and Family Characteristics	MD in Fall Kindergarten Only *Mean* (*SD*) *N* = 301	MD in Spring Kindergarten Only *Mean* (*SD*) *N* = 283	MD in Both Spring and Fall Kindergarten *Mean* (*SD*) *N* = 404	No MD in Either Spring or Fall Kindergarten *Mean* (*SD*) *N* = 6,904
Age in months	65.05 (3.44)	65.38 (4.30)	65.45 (4.79)	66.52 (4.31)
SES	–.37 (.60)	–.25 (.55)	–.54 (.53)	.15 (.80)
White	.76 (.43)	.54 (.50)	.52 (.50)	.83 (.37)
Female	.36 (.48)	.62 (.49)	.44 (.50)	.48 (.50)
Repeat kindergarten	.03 (.16)	.04 (.19)	.05 (.22)	.04 (.20)
Fall kindergarten reading difficulty	.44 (.50)	.23 (.42)	.59 (.49)	.03 (.18)
Approaches difficulty	.23 (.42)	.18 (.38)	.42 (.49)	.07 (.25)
IEP	.06 (.24)	.16 (.37)	.20 (.40)	.06 (.24)

Note: Estimates are weighted by child-level sampling weights. MD = mathematics difficulties; SES = socioeconomic status; IEP = Individualized Education Plan.

throughout the analysis to account for unequal probability sampling and nonresponse in the ECLS-K.

We entered the study's predictors sequentially. Collectively, however, and because our analyses statistically controlled for variation in a child's sociodemographic characteristics, they should provide relatively conservative estimates of the extent to which a set of educationally relevant factors, including the child's initial reading skill, whether he or she had been retained, the frequency of his or her attention to task and other learning-related behaviors, and whether he or she was identified by kindergarten as having a disability, predicted a child's early (i.e., spring of first grade) knowledge of mathematics and skills growth over his or her elementary school years. Because we statistically controlled for both sociodemographic and more educationally relevant factors, our analyses also should provide relatively conservative estimates of the effects of the timing and persistence of the kindergarten child's MD on his or her subsequent rate of growth in learning mathematics while in elementary school.

Results

Table 2 shows descriptive statistics for each of the four groups of children defined by their MD status in the fall and spring of kindergarten. Our analytical sample consisted of 6,904 children who displayed MD at neither time point, 404 who displayed MD at both fall and spring of kindergarten, 283 who displayed MD in spring only, and 301 who displayed MD in fall only.

The sociodemographic variables, as well as the more educationally relevant covariates (i.e., reading difficulty, infrequent learning-related behaviors, retention, and IEP placement) are patterned as expected across the four groups. For example, those children displaying MD at both the fall and spring of kindergarten have the lowest average SES score. These children are also more likely to be retained and display reading difficulties, engage in learning-related behaviors less frequently, and have an IEP. Specifically, children with MD at both the beginning and end of kindergarten have by far the lowest average SES (–.54); those with MD at one of the kindergarten time points also have relatively low SES (–.37 and –.25). In contrast, those with MD at neither time point averaged an SES of .15. This is about 1 standard deviation above those with MD at both time points. Children with MD at one or both kindergarten time points are also much less likely to be White than those with MD at neither time point. Even more disparate is the percentage with reading difficulties in the fall of kindergarten. About 60% of those with MD at both time points displayed reading difficulties. Reading difficulties occurred for, respectively, 44% and 23% of those with MD in the fall only and spring only of kindergarten. In contrast, reading difficulties were experienced by only 3% of students with MD at neither time point. Similar, but less extreme, patterns are observed for the four groups when the variable of interest is whether a teacher rated a child as infrequently engaging in learning-related behaviors while completing classroom tasks. Children with MD at both time points had the highest IEP placement rate.

Table 3
Kindergarten Through Fifth-Grade Mathematics Tests Scores for the Analytical Sample, by MD Status

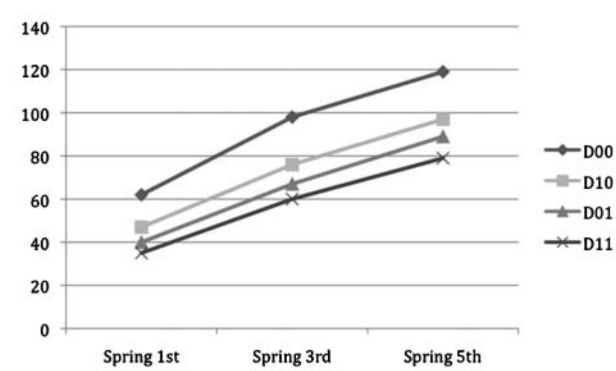
MD Categorization	Fall Kindergarten	Spring Kindergarten	Spring First Grade	Spring Third Grade	Spring Fifth Grade
MD in fall kindergarten only					
N	326	326	323	259	211
Mean (*SD*)	12.96 (1.18)	26.18 (4.12)	47.12 (10.79)	76.45 (16.43)	96.93 (17.45)
MD in spring kindergarten only					
N	325	325	323	245	180
Mean (*SD*)	17.18 (2.10)	19.30 (1.77)	39.96 (10.38)	67.04 (14.29)	88.55 (20.34)
MD in both fall and spring kindergarten					
N	465	465	461	352	239
Mean (*SD*)	11.80 (1.62)	17.09 (2.72)	34.99 (9.72)	59.86 (10.97)	79.35 (17.83)
No MD in either fall or spring kindergarten					
N	6776	6776	6718	5764	4578
Mean (*SD*)	25.48 (8.40)	36.67 (11.03)	62.60 (15.54)	98.31 (19.06)	118.71 (18.42)

Note: Estimates are weighted by child-level sampling weights. MD = mathematics difficulties.

Growth Trajectories for Each of the Four Groups

Table 3 displays the four groups of children's means and standard deviations of the Mathematics Test scores from kindergarten through fifth grade. The mean scores of all groups are increasing. However, and over time, the mean scores for those children with MD at both kindergarten time points remain consistently and substantially lower than those of the other groups. As hypothesized, children with MD in spring of kindergarten only have the next lowest scores during the subsequent 5-year time point. The next lowest scores during the spring of kindergarten, first grade, third grade, and fifth grade are for those with MD in the fall of kindergarten only. Those children displaying MD in both the fall and spring of kindergarten scored, on average, more than 2 standard deviations lower on the fifth grade administration of the Mathematics Test than those children who had not displayed MD in kindergarten (i.e., 79.35 vs. 118.71). Figure 2 displays the first through fifth grade mean Mathematics Tests IRT scores of children on the basis of their MD categorizations in kindergarten. Following the examination of these mean test scores over time, we conducted regression analyses to estimate the magnitudes of these growth differences more precisely, both without and with controls for a range of possible confounds.

Figure 2
Growth Trajectories (Mean Mathematics Test IRT Score), First Through Fifth Grades, by Kindergarten MD Categorization



Note: D00 = No MD in either fall or spring of kindergarten; D10 = MD in fall of kindergarten only; D01 = MD in spring of kindergarten only; D11 = MD in both fall and spring of kindergarten; MD = mathematics difficulties; IRT = item response theory.

Table 4 displays the number and percentage of kindergarten children in the respective MD groupings still displaying MD in first, third, or fifth grade. Children were very likely to later be displaying MD if they repeatedly displayed MD in kindergarten. About 70% of those repeatedly displaying MD in kindergarten were experiencing MD in first, third, or fifth grade. In contrast, less than 5% of those who did not display MD in kindergarten displayed MD in these grades. A larger percentage of children experiencing MD in the spring of kindergarten were later experiencing MD than were those who experienced MD in the fall of kindergarten.

Table 4
Number and Percentage of Children Displaying MD in First, Third, or Fifth Grade, by Their MD Categorization in Kindergarten

Kindergarten MD Categorization	MD in Spring of First Grade	MD in Spring of Third Grade	MD in Spring of Fifth Grade
MD in fall kindergarten only	78/323 (24%)	68/259 (26%)	59/211 (28%)
MD in spring kindergarten only	139/323 (43%)	113/245 (46%)	82/180 (46%)
MD in both fall and spring of kindergarten	314/461 (68%)	245/352 (70%)	156/239 (65%)
No MD in either fall or spring of kindergarten	252/6,718 (3%)	236/5,764 (4%)	224/4,578 (4%)

Note: MD = mathematics difficulties.

Results From the Multilevel Regression Analyses

Table 5 displays results from a hierarchy of models that we fit to the data for all children's test scores during the 5 years subsequent to kindergarten. Models 1 through 4 include an increasing number of predictors of kindergarten children's first through fifth grade mathematics intercepts and rates of skills growth.

Model 1 is a baseline model with no predictor variables. The reliability estimates of the intercept and the linear slope parameters in the baseline model were .827 and .421, respectively, providing positive evidence for the exploration of systematic relationships between person-level predictors and the growth parameters (Raudenbush & Bryk, 2002). Model 2 adds dummy variables for the three categories of kindergarten MD status: fall only (D10), spring only (D01), and fall and spring (D11). The reference group is children with MD in neither kindergarten time point. Here, we see clear support for the predictive utility of these categorizations of MD. As hypothesized, children with MD in both kindergarten time points displayed the lowest intercepts and growth rates during the subsequent 5 years (i.e., –29.17 and –2.91, respectively, where these coefficients indicate the difference in rates for these groups and the base category of children without MD at either kindergarten time point), followed in sequence by those with MD in spring only and those with MD in fall only. All three coefficients are statistically significant.

Model 3 adds the sociodemographic and kindergarten retention variables to the equation. These are all significantly associated with the math intercept and growth rate, except for repeating kindergarten. Older children begin with slightly higher scores, but their mathematics performance grows at a slightly slower rate than younger children. The mathematics performance of those from higher SES families begins higher and grows faster than that of children from lower SES families. The mathematics performance of White children begins higher and grows faster than that of African American children. The mathematics performance of females begins lower and grows slower than that of males. After controlling for these variables, the effects of the kindergarten MD category variables decrease somewhat in magnitude. However, they remain statistically significant and continue to show the same relative (to each other) magnitudes as those in the previous model. Children with MD in both the fall and spring of kindergarten end first grade averaging lower scores (i.e., –22.62) and displaying lower skills growth between the end of first grade and the end of fifth grade (i.e., –2.40 less over each 2-academic-year interval) than children who had not displayed MD during the two kindergarten time points.

Model 4 adds the fall kindergarten reading difficulty, infrequent learning-related behaviors, and IEP placement variables to the regression equation. Pseudo R^2 for Model 4 is 46.1% for the intercept parameter and 36.2% for the slope parameter. Infrequent learning-related behaviors and IEP placement significantly reduce the child's subsequent math intercept, but none of these factors significantly affects the growth rate. Furthermore, adding these variables to the regression leads to little change in the effects of the sociodemographics. The effects of the kindergarten MD variables are modestly reduced, but they remain significant, and the pattern of their relative magnitudes is unchanged. The conclusion is that these kindergarten measures of MD, along with sociodemographic factors, including age, social class background, race, and gender, are key predictors of a child's mathematics trajectories for the elementary school years following kindergarten.

Discussion

We estimated the growth trajectories of children entering kindergarten with one of four categories of learning difficulties in mathematics. These were (a) MD in the fall of kindergarten only, (b) MD in the spring of kindergarten only, (c) MD in both fall and spring of kindergarten, and (d) MD during neither time point. The first group displayed MD after more informal preschool

Table 5
Mathematics Linear Growth Model

Kindergarten Predictors	Model 1 Intercept	Model 1 Slope of Time	Model 1 Slope of Time Square	Model 2 Intercept	Model 2 Slope of Time	Model 2 Slope of Time Square	Model 3 Intercept	Model 3 Slope of Time	Model 3 Slope of Time Square	Model 4 Intercept	Model 4 Slope of Time	Model 4 Slope of Time Square
Intercept	59.63*	20.82*	–1.77*	62.79*	21.10*	–1.77*	59.58*	20.45*	–1.77*	60.80*	20.55*	–1.77*
D10				–16.55*	–1.57*		–12.54*	–1.57*		–11.74*	–1.30*	
D01				–24.25*	–1.90*		–18.90*	–1.45*		–17.51*	–1.29*	
D11				–29.17*	–2.91*		–22.62*	–2.40*		–19.69*	–1.96*	
Age in months							.71*	–.19*		.72*	–.20*	
SES							5.69*	.55*		5.46*	.53*	
White							6.29*	1.25*		6.24*	1.35*	
Female							–3.43*	–.70*		–4.19*	–.75*	
Repeat kindergarten							–4.33	–.59		–3.81	–.62	
Fall kindergarten reading difficulty										–.12	–.50	
Approaches difficulty										–6.44*	–.55	
IEP										–6.70*	–.06	
Correlation between intercept and slope		.36			.24			.22			.21	

Note: D10 = MD in fall but not spring of kindergarten; D01 = MD in spring but not fall of kindergarten; D11 = MD in both fall and spring of kindergarten; reference group is no MD in either fall or spring of kindergarten. Estimates are weighted by child-level sampling weights. N = 19,653, Level 1 units; N = 7,892, Level 2 units. Age, SES, fall kindergarten Reading Test score, Approaches score grand-mean-centered, other predictors are uncentered. MD = mathematics difficulties; SES = socioeconomic status; IEP = Individualized Education Plan.
$*p < .05$.

instruction but seemed to have overcome their learning disadvantage after receiving more formal kindergarten instruction. The second group did not display learning difficulties after receiving informal preschool instruction but did display such difficulties after receiving more formal instruction during kindergarten. The third group had difficulties despite receiving both informal and formal instruction. The final group had difficulties in neither period. Our results provided empirical support for these categorizations as useful predictors of kindergarten children's mathematics learning over their subsequent elementary school years. We observed the highest growth for children with MD at neither kindergarten time point. Children with MD at the beginning of kindergarten, but who had overcome this MD by the end of kindergarten, displayed somewhat lower growth. We observed even lower growth for children without MD when kindergarten began but who were now displaying MD by the end of kindergarten. Those children with MD at both the beginning and end of kindergarten displayed the lowest growth.

One conclusion supported by our results is that educators should consider evaluating the relative persistence of the kindergarten child's MD. Those children repeatedly displaying MD during their kindergarten school year are likely to require intensive early intervention effects if they are to avoid failing to become mathematically proficient over the course of their elementary school years. The study's descriptive statistics highlight the magnitude of this "persistence effect." The average fifth grade mathematics score for those repeatedly displaying MD in kindergarten was more than 2 standard deviations lower than the average fifth grade mathematics score for those who had not displayed such MD in kindergarten.

Our analyses also allowed us to investigate the extent to which mathematics growth trajectories are consistent with (a) a cumulative growth model or (b) a lag model. Our results support the cumulative growth model. Children entering kindergarten with MD of some type continued to display lower skills growth over their elementary school years than children entering kindergarten without MD. Those with the most intransient type of MD (i.e., those experiencing MD at both fall and spring of kindergarten) had by far the lowest subsequent math growth rates of all children. By contrast, children with MD at neither time point had by far the highest subsequent math growth rates. Those children displaying even variable-type MD in kindergarten averaged slower growth over the length of their elementary school years and, by the end of fifth grade, were performing 1 to 1.5

standard deviations lower on a measure of their mathematics knowledge than their non-MD peers.

We estimated regression models of mathematics growth that, in addition to dummy variables for the three types of MD, also included sociodemographic covariates and measures of whether or not the child had reading difficulties at the beginning of kindergarten, whether or not the child infrequently engaged in learning-related behaviors, and whether or not the child was provided with an IEP in kindergarten. The sociodemographic variables—age, social class background, race, and gender—were significant predictors of mathematics skills growth even when entered alongside the dummy variables for the categories of MD. However, the other covariates (reading difficulty, learning behavior difficulties, placement with an IEP) had no statistically significant effects on the children's subsequent growth rates once the MD and sociodemographic variables were controlled. In addition, although controlling the sociodemographic and the other covariates reduced the magnitudes of effect of the MD category variables, these MD variables remained statistically significant and quite large in magnitude and maintained the pattern (that is, the ordering in their magnitude) hypothesized at the beginning of this study.

We conclude that, when considered together, measures of MD taken in fall and spring of kindergarten can function as key predictors of children's subsequent elementary school growth trajectories in mathematics. Our estimates indicated a clear ordering of the extent to which a child is experiencing MD and so may be in need of additional, specialized instructional assistance. Furthermore, and once these measures are accounted for, it is the child's sociodemographics, but not kindergarten measures of reading or behavioral difficulties, nor IEP placement, that are predictive of subsequent mathematics growth. (We also note the relatively large size of the study's sample, which should have provided ample statistical power to detect such effects.) To our knowledge, estimates of the effects of the child's sociodemographics on his or her mathematics learning over the length of elementary school, after careful controls for the prior incidence of MD (i.e., the "autoregressor") and these more educationally relevant factors, have not been previously reported (although see Jordan et al., 2003, for a similar study over a shorter time frame).

Limitations

Our study has several limitations. We included only children whose race was identified by his or her mother as White, non-Hispanic or Black/African American, non-Hispanic. We did so to provide a more accurate estimate of the effects of relative reading skill for those children who were so identified. However, and as a result, we were unable to estimate to what extent children from other racial or ethnic groups (e.g., Hispanics, Asians) display relatively greater or lesser proficiency in mathematics over time. This is a limitation of other investigations as well (e.g., Jordan et al., 2003; Mazzocco & Thompson, 2005) and should be addressed. We used a cutoff of 10% to establish whether kindergarten children were experiencing MD at the testing dates in fall and spring of kindergarten. Our analyses may have yielded different estimates if we had used other cutoff scores (Murphy, Mazzocco, Hanich, & Early, 2007). Our study's design does not allow for causal inferences. Experimental studies are necessary to properly evaluate an intervention's efficacy and effectiveness (Shadish, Cook, & Campbell, 2002). Our analyses used data from the fall of kindergarten to the spring of fifth grade. Use of such data extends prior investigations, which typically have been limited to the primary grades (e.g., Aunola et al., 2004; Diperna et al., 2007; Fuchs et al., 2006; Jordan et al., 2007; Jordan et al., 2006; Mazzocco & Thompson, 2005). However, we cannot say whether and to what extent the study's data patterns continue to hold as children move into middle and high school.

Study's Contributions and Implications

This study makes both methodological and substantive contributions. Methodologically, our study's use of a measure of parent- or guardian-reported education and income should have resulted in a more accurate estimate of the effects of SES on children's learning of mathematics. Prior investigations have typically measured the effects of SES less directly, by using school reports of a child's eligibility for free or reduced lunch (e.g., Jordan et al., 2003) or census variables measured for the school's ZIP code (Lachance & Mazzocco, 2006), as well as dichotomously (i.e., low income vs. not low income). This may help explain differences between our findings and those of others. Prior studies have also typically had to rely on small convenience samples of children attending particular schools and sometimes low-performing children in these schools (e.g., Cirino et al., 2007; Fuchs et al., 2006; Jordan et al., 2007; Mazzocco & Thompson, 2005). However, reliance on such samples may limit the extent to which certain subgroups of children (e.g., those repeatedly displaying MD in kindergarten) may be identified as in need of early intervention (Bennett et al., 1998; Campbell et al., 2000). Our use of data from a large number of children, who themselves were participating in a nationally representative sample, should have yielded more accurate and population-based estimates of a given risk factor's effects.

Substantively, our study helps identify factors that might be targeted by interventions designed to increase the mathematics proficiency of children experiencing MD in kindergarten. By using MD measures at both the beginning and end of kindergarten, and by categorizing children into one of four groups—MD in fall only, MD in spring only, MD at both time points, MD at neither time point—we identified a factor that functioned as a robust and reliable predictor of children's mathematics growth over their subsequent 5 years of schooling. With these variables and sociodemographics controlled, kindergarten reading difficulty, learning behavior difficulty, and IEP placement had no statistically significant effect on subsequent math growth. This suggests that the four-group characterization of kindergarten MD provides a relatively accurate and powerful index of the magnitude and severity of the later difficulties that an individual child is likely to face when attempting to learn mathematics.

The study's results indicate that intervention for MD needs to begin very early. Those children who manifest any of the three patterns of MD at the beginning and/or end of kindergarten are likely to show substantially lower mathematics skills growth rates throughout their elementary school years. Even children who experienced mathematics learning difficulties in preschool, but to some extent overcame these difficulties after receiving more formal instruction during kindergarten, had lower subsequent growth trajectories than those who experienced no such difficulties in preschool. A clear implication is that those young children who are repeatedly experiencing learning difficulties in mathematics should begin to receive additional assistance—which itself should be delivered at least by the end of kindergarten—if they are to become mathematically proficient by the end of elementary school.

Note

1. The percentages of children who had scores on the kindergarten administration of the Reading Test were as follows: White, 89.09%; Black, 89.09%; Hispanic (race specified), 66.1%; Hispanic (race not specified), 58.21%; and Asian, 66.91%.

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