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Mathematics Deficiencies in Children with Very Low Birth Weight or Very Preterm Birth

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Abstract

Children with very low birth weight (VLBW, < 1500 g) or very pre-term birth (VPTB, < 32 weeks gestational age or GA) have more mathematics disabilities or deficiencies (MD) and higher rates of mathematics learning disabilities (MLD) than normal birth weight term-born children (NBW, > 2500 g and > 36 weeks GA). MD are found even in children without global disorders in cognition or neurosensory status and when IQ is controlled, and they are associated with other learning problems and weaknesses in perceptual motor abilities and executive function. Factors related to poorer mathematics outcomes include lower birth weight and GA, neonatal complications, and possible abnormalities in brain structure. While little is known about the nature of MD in these children, studies of MLD in other neurodevelopmental disorders and in children with learning disabilities provide useful models for further investigation. Further investigation of the neuropsychological and neuropathological correlates of distinct types of mathematics difficulties is also needed. Studies along these lines will yield information about the unique features of MD in children with VLBW/VPTB and about the nature and origins of poor mathematics achievement more generally.

Keywords: very low birth weight, mathematics learning disabilities, neuropsychological impairment

Advances in neonatal intensive care have resulted in increasing numbers of survivors with very low birth weight (VLBW, < 1500 g, 3 lbs. 5 oz.) or very preterm birth (VPTB, < 32 weeks gestational age, or GA) (Hintz *et al.*, 2005). Although GA cut-offs provide a more meaningful basis for classifying the degree of prematurity, information on GA can be unreliable and birth weight markers are frequently used instead of GA to classify the degree of prematurity and fetal growth restriction. For this reason, children have been identified in the literature by either criterion and are referred to here as children with VLBW/VPTB. These children have high rates

of neurological and other medical complications at birth and they are at risk for a variety of neurodevelopmental problems (Taylor, in press). Developmental consequences of VLBW/VPTB range from cerebral palsy and mental retardation to more subtle deficits in cognitive abilities, academic achievement, and behavior in survivors without major handicapping conditions. Children born at more extreme degrees of VLBW/VPTB, such as those with extremely low birth weight (< 1000 g, 2 lbs. 3 oz.) or extremely preterm birth (GA < 28 weeks) are at substantially higher risk for these disorders than are children with higher birth weight or GA.

Deficits in academic achievement occur in all basic skill areas (Klebanov *et al.*, 1994; Saigal *et al.*, 2000; Grunau *et al.*, 2002; Anderson *et al.*, 2003; Schneider *et al.*, 2004; Feder *et al.*, 2005; Litt *et al.*, 2005; Taylor *et al.*, 2000, 2006). These deficits are evident by school entry, persist throughout the school-age years, and are costly to treat (Chaikind and Corman, 1991; Saigal *et al.*, 2000; Pharoah *et al.*, 2003; Roth *et al.*, 2004; Lefebvre *et al.*, 2005). Many survivors have relatively selective impairments in academic skills, possibly related to specific neuropsychological weaknesses (Litt *et al.*, 2005). Problems in mathematics are especially common but poorly understood.

In this article, we first review findings documenting the adverse effects of VLBW/VPTB on mathematics skills and summarize knowledge regarding factors related to these skills. Because the nature of mathematics difficulties in children with VLBW/VPTB has not been described in detail, we then consider studies of these problems in other populations, including children with other neurodevelopmental disorders and with developmental learning disabilities. These studies suggest ways to enhance knowledge of mathematics outcomes in children with VLBW/VPTB. In the final section we summarize methodological weaknesses of existing studies and promising directions for future research. Throughout the paper, the generic term mathematics disabilities (MD) refers to mathematics problems or deficiencies more broadly, while

mathematics learning disabilities (MLD) refers to problems that are not accompanied by low global cognitive ability (e.g., as defined by IQs < 80-85) or neurosensory disorders, such as cerebral palsy, vision, or hearing impairments.

Evidence for MD And MLD in Children with VLBW/VPTB

Compared with groups of children with normal birth weight children born at term (NBW, ≥ 2500 g and 37 weeks GA), VLBW/VPTB cohorts consistently score at lower levels on tests of mathematics and receive lower teacher ratings of classroom performance in mathematics (Klebanov *et al.*, 1994; Botting *et al.*, 1998; Saigal *et al.*, 2000; Taylor *et al.*, 2002; Anderson *et al.*, 2003; Hagen *et al.*, 2006). The tests of mathematics skills administered in these studies have been limited to age standardized measures that assess accuracy in carrying out a range of arithmetic operations, most typically using either the Arithmetic subtest of the Wide Range Achievement Test (WRAT-R, WRAT3, WRAT4) or the Calculation and Applied Problems sub-tests of the Woodcock Johnson Tests of Achievement (original or revised versions). The Arithmetic and Calculation subtests measure written math skills (e.g., addition, subtraction, multiplication, division) and Applied Problems assesses arithmetic problem solving.

VLBW/VPTB samples score less well than NBW control groups on mathematics tests, even when excluding children with mental retardation or neurosensory disorders (i.e., cerebral palsy, vision, or hearing impairments) or when controlling for IQ (Klein *et al.*, 1989; Klebanov *et al.*, 1994; Botting *et al.*, 1998; Saigal *et al.*, 2000; Taylor *et al.*, 2000; Taylor *et al.*, 2002; Anderson *et al.*, 2003). Results from several studies also indicate that children with VLBW/ VPTB have more pronounced impairments in mathematics than in reading (Klebanov *et al.*, 1994; Breslau *et al.*, 2001; Taylor *et al.*, 2002; Anderson *et al.*, 2003).

As further evidence for specific forms of MD, MLD are also more common in samples of children with VLBW/VPTB than in NBW groups. In the first phase of a longitudinal study conducted in Cleveland, Ohio, Taylor *et al.* (1995) examined rates of MLD and other forms of learning disabilities (LD) at mean age 7 years in a population cohort of children with < 750 g birth weight and matched groups of children with 750-1499 g birth

weight and with NBW. Only children without neurosensory disorders and with standard scores of at least 80 on a measure of global cognitive ability were included. Subtests of the Woodcock Johnson Tests of Achievement-Revised were administered to assess mathematics (Calculation and Applied Problems), reading (Letter/ Word Identification), and spelling (Dictation). "Low achievement" LD was defined by standard scores ≤ 90 on the achievement subtests, and "discrepancy-based" LD by scores below expectations (by at least 1.5 standard errors of the estimate) based on the child's global cognitive ability. Results revealed higher rates of low achievement LD in the < 750 g group compared with NBW controls on Calculation, Applied Problems, and Letter/Word Identification. The < 750 g group also had higher rates of discrepancy-based LD in Applied Problems. Differential rates of LD between the < 750 g and NBW groups were particularly large for the mathematics subtests, with rates of discrepancy-based LD in Applied Problems of about 60% in the < 750 g group compared with 15% in the NBW group. Rates of LD in the 750-1499 g group fell between those in the other two groups but were not significantly higher than those for the children with NBW. Similar results were obtained in comparing the three groups followed in the Cleveland longitudinal study in rates of LD at mean age 11 years (Litt *et al.*, 2005). The findings from the latter study also indicated a high degree of concordance of low achievement LD across the two assessments.



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In another study, Grunau *et al.* (2002) identified LD in mathematics, reading, and written output in a sample of children with ≤ 800 g birth weight and in

NBW controls. Only children with typical neurological development, with either a Wechsler Verbal or Performance IQ of at least 85, were included, and mathematics skills were assessed using the Arithmetic subtest of the WRAT-R. LD on this and other achievements tests were identified based on standard scores of less than 85. The investigators found that 46% of the ≤ 800 g birth weight group had LD in Arithmetic compared with only 7% of the controls. The results of this study also documented a high rate of LD across multiple skill areas, with 10 of 22 children having LD in both Arithmetic and a reading measure. This rate of combined LD in mathematics and reading was similar to that observed in the study by Litt *et al.* (2005), where about half of the children with low achievement LD in mathematics also had low achievement LD in reading. Conversely, these data indicate that a sizable proportion of children with more extreme low birth weight have isolated MLD.

Factors Related to MD

Degree of Low Birth Weight/GA

The extent of MD varies along a continuum or "gradient" in proportion to the degree of VLBW/VPTB (Klebanov *et al.*, 1994; Saigal *et al.*, 2000; Taylor *et al.*, 2000; Anderson *et al.*, 2003; Schneider *et al.*, 2004). Breslau *et al.* (2004) found a gradient effect on mathematics skills extending up to 2500 g birth weight. Specifically, MD in the low birth weight group relative to NBW controls were greater for children with VLBW but were also found in children with 2001-2500 g birth weight. A similar gradient is evident in studies of MLD. For example, Taylor *et al.* (1995) found that children with < 750 g birth weight had a higher rate of LD in Applied Problems than children with 750-1499 g birth weight; and Johnson and Breslau (2000) found that the rate of MLD among male children increased with lower birth weight throughout the ≤ 2500 g range.

Medical and Brain Correlates

Poorer mathematics skills at school-age are related not only to the degree of VLBW/VPTB but also to neonatal complications and postnatal neurological abnormalities. In the Cleveland VLBW sample, scores on the Woodcock-Johnson Calculation and Applied Problems subtests at 7 years were independently associated with more neonatal compli-

cations and lower birth weight (Taylor *et al.*, 1998). Other studies indicate associations of poorer mathematics performance with more severe intraventricular hemorrhage, chronic lung disease (defined by placement on a ventilator for at least 36 weeks corrected age), treatment with postnatal steroids, necrotizing enterocolitis (infection and inflammation of the intestines), and longer neonatal hospitalization (Vohr *et al.*, 2003; Sherlock *et al.*, 2005; Taylor *et al.*, 2006; Short *et al.*, 2007).

Postnatal medical factors related to poorer educational outcomes include subnormal head circumference, vision problems, and abnormalities in brain structure. Peterson *et al.* (2006) observed that smaller head circumference at age 8 years was associated with lower scores on Calculation in children with VLBW from the Cleveland longitudinal study. These differences were found even when controlling for neurosensory abnormality, SES, sex, weight for GA, and neonatal medical complications. In examining outcomes of retinopathy of prematurity in a sample of children with 1250 birth weight, Msall *et al.* (2004) noted that poor visual acuity was associated with lower teacher ratings of mathematics. To our knowledge, only two studies have examined the postnatal neuropathological correlates of mathematics skills in children with VLBW/VPTB. Using magnetic resonance imaging (MRI), Isaacs *et al.* (2000) measured hippocampal volumes in a sample of adolescents with VLBW/VPTB accompanied by neonatal respiratory disease. Compared with age-matched adolescents with normal birth histories, the VLBW/VPTB group had a selective impairment in mathematics computation that was accompanied by reduced bilateral hippocampal volumes. Group differences were not found in total intracranial volume, suggesting that structural alternations in the hippocampus may have contributed to the VLBW/VPTB group's MLD. In a subsequent study, Isaacs *et al.* (2001) compared children from this same cohort whose scores in mathematics computation fell below expectation based on IQ with children from the cohort whose scores were consistent with IQ. MRI-based analysis revealed a reduction in brain volume in the group with MLD that was isolated to the left intraparietal lobe.

Based on evidence from functional MRI (fMRI), Dehaene *et al.* (2003) has postulated three brain regions that contribute uniquely to mathematics skills:

an area of the intraparietal sulcus underlying quantity processing, a region in the left angular gyrus responsible for verbal processing of numbers, and a posterior superior parietal system related to spatial attention. Frontal brain regions are also selectively activated during mathematics tasks (Rickard *et al.*, 2000). Patterns of activation that vary from those found in adults or children without VLBW/VPTB would provide insights regarding compensatory brain organization. As illustrated by an fMRI study of children with phonological processing disorder (Noble *et al.*, 2006), one possible outcome of such investigation is that children with activations in brain regions not typically engaged in mathematics tasks may have better mathematics skills than children with more typical, though perhaps diminished, activations. Several studies have observed atypical activations in response to cognitive tasks in survivors of VLBW/VPTB, supporting the possibility of compensatory mechanisms (e.g., Nosarti *et al.*, 2006). To our knowledge, however, no studies of these children have examined activation patterns during mathematics tasks.

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Cognitive Correlates

Several studies of children with VLBW/VPTB have found that selective deficits in mathematics are accompanied by specific cognitive weaknesses, most often in the domains of visual spatial and perceptual motor abilities and executive function. Rickards *et al.* (2001), for example, found deficits in mathematics but not in reading or spelling in comparing their VLBW cohort at age 14 years with a NBW group. The VLBW cohort also

had impairments on tests of visual processing, visual memory, and visual perceptual organization, but not in most IQ subtests. In another VLBW sample, Klein *et al.* (1989) found only deficits in mathematics and perceptual motor skills when analysis was limited to children with normal IQ. Similarly, in comparing their < 750 g birth weight and NBW groups, Taylor *et al.* (2002) observed that only differences in mathematics and a perceptual planning factor composite remained when controlling for IQ.

Studies that have directly examined the cognitive correlates of mathematics skills in VLBW/VPTB samples reveal associations with both general ability as assessed by IQ and multiple specific neuropsychological skills. To illustrate, Taylor *et al.* (2006) found that measures of global mental processing, executive function, motor skills, and picture naming were related to Woodcock-Johnson Calculation at mean age 8 years in a cohort of children with < 1000 g birth weight. Assessment of a sample with ≤ 800 g birth weight by Grunau *et al.* (2002) revealed correlations of Arithmetic scores on the WRAT-R with Wechsler Verbal IQ and performance on a design copying test. In a further study of this cohort, weaknesses in Arithmetic were also associated with deficits in motor coordination (Holsti *et al.*, 2002).

Other studies suggest that specific neuropsychological skills are related to mathematics achievement even after taking global cognitive ability into account. Taylor *et al.* (1998) showed that measures of attention administered to children in the Cleveland longitudinal study at 7 years were related to performance on Woodcock-Johnson Calculation and Applied Problems when controlling for IQ. Later follow-up of this sample at 11 years revealed that measures of perceptual planning and verbal working memory in the children with VLBW were each associated with mathematics performance independent of IQ (Litt *et al.*, 2005). Findings from structural equation modeling of this data set by Taylor *et al.* (2002) suggest that the effects of VLBW on mathematics outcomes were mediated by some of these same measures, providing even stronger support for a neuropsychological basis of MD in this sample.

Results from several studies indicate that cognitive abilities in early childhood can forecast later MD. Sullivan and McGrath (2003) observed associations between motor performance at 4

years and mathematics at 8 years in a sample comprised of children with ≤ 34 weeks GA and healthy NBW controls. Botting *et al.* (1998) demonstrated a similar association between motor skills at age 6 years and performance on a written mathematics test at 12 years in children with VLBW and their classmate controls. In another longitudinal study, Schneider *et al.* (2004) found that a composite of mathematics reasoning, size estimation, and visualization given to a VLBW/ VPTB cohort and matched NBW controls was related to tests of IQ and letter, number, and phonological knowledge administered 2 years earlier. Finally, Breslau *et al.* (2001) found that mathematics skills as measured by the Woodcock-Johnson Psycho-Educational Battery-Revised at age 11 years in their sample of children with $\leq 2,500$ g birth weight and NBW controls was predicted by IQ, perceptual motor, and phonological processing tasks administered at age 6 years. IQ at age 6 years also predicted mathematics skills in this sample at 17 years (Breslau *et al.*, 2004).

Sex and Age Differences in Mathematics Outcomes

Some studies of children with VLBW/VPTM suggest more MD and MLD in males than in females (O’Callaghan *et al.*, 1996; Johnson and Breslau, 2000), though other investigations have not found sex differences in this population (e.g., Saigal *et al.*, 2000; Taylor *et al.*, 2000; Grunau *et al.*, 2004). With respect to potential age differences in MD, impairments on tests of mathematics achievement in VLBW/ VPTB cohorts are evident from the early school-age years and persist into adolescence and young adulthood (Saigal *et al.*, 1990; Taylor *et al.*, 1995; Botting *et al.*, 1998; Saigal *et al.*, 2000; Rickards *et al.*, 2001; Hack *et al.*, 2002). To our knowledge, only two studies have examined changes in mathematics performance longitudinally in children with low birth weight. Saigal *et al.* (2000) observed a greater decline in standard scores on the Arithmetic subtest of the WRAT-R from ages 8 years to adolescence (12–16 years) in a subsample of their cohort with <750 g birth weight compared with full-term controls. They suggest that the decline may reflect increases with age in demands on conceptual skills and written computations. Breslau *et al.* (2004), however, found stable MD across age in following their sample of children with 2500 g birth from ages 11 to 17 years. The differences between these two stud-

ies may reflect the greater concentration of higher risk children in the cohort followed by Saigal *et al.* (2000). While few longitudinal studies have been conducted, evidence to date suggests that the presence of early MD is a marker of ongoing impairment and is unlikely to reflect developmental lag.



Because testing has been restricted to composite measures of competencies, this research has not differentiated the effects of VLBW/VPTB on different types of mathematics skills, such as the ability to retrieve mathematics facts, carry out procedures for solving written or story problems, apply mathematics concepts, or engage in nonverbal or visual-spatial reasoning.



Methodological Critique of the Existing Literature on Mathematics Outcomes of VLBW/VPBT

Studies of the effects of VLBW/ VPTB on mathematics have been subject to the same methodological limitations that have plagued research on other outcomes (Aylward, 2005). To begin with, the consequences of VLBW/ VPTB vary across eras and centers due to subtle differences in perinatal and neonatal management practices (Pinto-Martin *et al.*, 2004; Vohr *et al.*, 2004). For this reason, outcomes are expected to vary to some extent across sites and birth cohorts. Second, many past studies have failed to carefully match NBW comparison groups to VLBW/VPTB samples or to control for background factors, such as socioeconomic status, histories of educational interventions, genetic background and parenting characteristics, and prenatal drug and alcohol exposures, in analysis of group dif-

ferences. A recent population study confirmed the importance of the home environment and early learning experiences as influences on subsequent mathematics achievement at 10 years (Melhuish *et al.*, 2008). The consequences of VLBW/VPTB on mathematics skills may be best assessed in studies that take as many of these other factors into account as is feasible. Third, MD are typically described only for total VLBW/ VPTB samples, rather than in high-risk subgroups classified according to birth weight/GA, neonatal complications, or postnatal neurological status. Research on “person-level” effects, as opposed to the more traditional emphasis on “variable-level” effects, supports the viability of this subgrouping approach (Muthen and Muthen, 2000). Other limitations include the need to consider the effect of major handicapping conditions, such as generalized mental deficiency and neurosensory deficits in evaluating outcomes, and to document effects in terms of group differences in both mean performance and impairment rates.

Methodological weaknesses that are particularly limiting in understanding the effects of VLBW/VPTB include the failure of past studies to assess distinct types of MD, examine theory-based hypotheses regarding underlying neuropsychological competencies, and track developmental changes in mathematics skills. Because testing has been restricted to composite measures of competencies, this research has not differentiated the effects of VLBW/VPTB on different types of mathematics skills, such as the ability to retrieve mathematics facts, carry out procedures for solving written or story problems, apply mathematics concepts, or engage in nonverbal or visual-spatial reasoning. Past studies have also neglected to examine the nature of errors on mathematics tasks for clues as to the basis of incorrect answers to problems. A related problem is that, unlike the broader field of MLD research, research on MD in children with VLBW/VPTM has been largely atheoretical and in general has failed to explore associations of MD with distinct cognitive functions such as working memory, processing speed, mental flexibility, and attentional control. With respect to longitudinal follow-up, few studies have assessed mathematics skills in children with VLBW/ VPTB across age, and none to our knowledge has examined different types of mathematics skills or error types over time.

MLD. Furthermore, potential implications for mathematics skills of insults to fronto-striatal and parietal-occipital pathways and the cerebellum are as yet unexplored (Allin *et al.*, 2001; Jakobson *et al.*, 2001; Woodward *et al.*, 2006).

A better understanding of the MD and treatment needs of children with VLBW/VPTB can be promoted in several ways. First, more comprehensive assessments of mathematics skills are required to clarify the nature of their MD. Examples include measures of errors or fluency in fact retrieval and numerical operations, computational strategies, magnitude estimation, and comprehension of mathematics concepts (Mazzocco, 1998, 2003; Ayr *et al.*, 2005; Gersten *et al.*, 2005; Barnes *et al.*, 2006). Such assessments may reveal subtle weaknesses that would otherwise go undetected and that may help to identify the unique features of MD in this population. Study of associations and dissociations between distinct varieties of MLD and disorders in reading or neuropsychological skills may also be useful in determining the types of problems to which children with VLBW/VPTB are most vulnerable. The literature on MLD in this and other child populations suggests that multiple cognitive skills contribute to development of mathematics skills. A major goal of research involving children with VLBW/VPTB is to isolate the reasons for their MD. A plausible working hypothesis is that some of these deficiencies are due to global cognitive weaknesses affecting learning more generally, while other problems reflect insult to brain regions or circuits of particular relevance to mathematics.

Like other developmental outcomes of VLBW/VPTB, mathematics skills vary considerably within cohorts. This variability can be attributed to several factors. Biological risks for poorer mathematics outcomes are lower birth weight or GA, neonatal medical complications, and postnatal abnormalities in head circumference and brain structure. Other potential influences on these outcomes include prenatal exposures to drugs or alcohol, family and genetic background, past learning experiences, and behavioral dispositions and motivation. Contextual factors, such as the academic demands and the supports available to meet these demands, may be of additional importance in assessing mathematics performance at school. Consideration of these multiple risk

and protective factors will clarify the effects of VLBW/VPTB and enhance prediction of individual outcomes.

In view of the fact that MD are more severe and selective in children with more extreme low birth weight or low GA, a sensible research strategy would be to focus on this segment of the VLBW/VPTB spectrum. It may also be useful to isolate high-risk subgroups with specific types of neonatal medical complications, such as chronic lung disease or neonatal brain insults. More information on residual neuropathology present at the time of follow-up from MRI would also illuminate the neural mechanisms contributing to mathematics difficulties, as would fMRI studies of brain activations during mathematics tasks.

Another important research direction is the study of early markers of mathematics difficulties in children with VLBW/VPTB and of the longer-term effects on academic progress and adult functioning. MD in school-age children are associated with weaknesses in global cognitive ability, perceptual motor skills, and academic readiness prior to or shortly after school entry (Breslau *et al.*, 2001; Hansen *et al.*, 2002; Sullivan and McGrath, 2003; Schneider *et al.*, 2004). However, we know little about associations of neuropsychological impairments with early mathematics skills such as number concepts and counting. Longitudinal investigations have the potential to discover atypical trajectories of skill development and identify factors associated with these trajectories (Ansari and Karmiloff-Smith, 2002). Cross-age assessment of distinct types of mathematics skills and investigation of age differences in their cognitive correlates, as exemplified in a study by Ayr *et al.* (2005), would also provide information on developmental changes in the nature of mathematics difficulties in this population. We do not know if MD in some areas, such as mathematics reasoning, emerge with age as distinct disabilities or represent the cumulative effects of poorly developed basic skills in domains such as fact retrieval, math procedures, or mental representations of number. Evidence for increasing deficits across age in perceptual motor skills and executive function in children with < 750 g birth weight (Taylor *et al.*, 2004) suggests that this subset of survivors may be especially prone to increasing difficulties in higher-level mathe-

matics skills, but this possibility has not been tested.

Given the frequency of math problems in children with VLBW/VPTB, interventions will be required to improve these outcomes. Methods that would have special relevance for children with VLBW/VPTB would be those that take into account their weaknesses in executive function, memory, and non-verbal abilities as well as their relative strengths in language (Litt *et al.*, 2005; Taylor, in press). Approaches similar to those used in previous studies of children with developmental MLD would be appropriate given the needs of these children for structure and explicit strategy training, extended practice, and help in applying skills across multiple settings and problem types (Barnes, 2008). Because outcomes of VLBW/VPTB are variable and needs may change with advancing age, flexibility will be required in accommodating to individual learning characteristics.

A related research direction is to explore reasons why many children with more extreme degrees of VLBW/VPTB function well academically despite high-risk birth (Anderson *et al.*, 2003). Acquisition of mathematics skills in these children may reflect relatively less severe neonatal brain insult but may also be related to greater brain plasticity or effective academic instruction. If so, study of these "success stories" may suggest ways to optimize the development of mathematics skills.

Research directed toward improved understanding of the nature and origins of MD in VLBW/VPTB samples will have several benefits. Practical benefits include information on the types and cognitive underpinnings of MD, so that these deficits can be more accurately identified and instructional interventions targeted to core areas of impairment. Knowing the types of MD to which children with VLBW/VPTB are most vulnerable will also help in designing interventions that may be broadly applicable to this population. Scientific benefits include the opportunity to examine specific neuropsychological and neural correlates of MD. Children with VLBW/VPTB are not only at high risk for selective deficits in mathematics but also have specific forms of neuropsychological impairment and neuropathology. Localized brain insults are in the very regions hypothesized to be most critical to math-

ematics skills. Study of these children thus affords a unique opportunity to investigate cognitive and neural factors underlying specific forms of MD. Additional scientific advantages include opportunities to examine the influence of comorbid reading disabilities on mathematics achievement and to explore the possibility that some children may have deficits in numeracy skills that can not fully explained in terms of domain-general neuropsychological impairments.

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