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The relation of verbal and nonverbal skills to basic numerical processing of preterm versus term-born preschoolers

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Abstract

Verbal and non-verbal skills significantly contribute to individual differences in children's numerical development at the group level. However, less is known about whether the nature of the relations between verbal and non-verbal systems and numerical cognition varies depending on the unique characteristics children bring into numerical learning. To better delineate these associations, we examined the association between verbal and non-verbal skills and symbolic numerical development in preterm-born ($n = 93$, < 37 weeks of gestation, PTB) and term-born children ($n = 104$). We showed that PTB preschoolers, as a group, were at a higher risk of falling behind on certain numerical tasks (cardinality), but not others (counting). There was, however, significant individual variability within the groups. Verbal and non-verbal skills contributed to the variability of children's numerical performance, but differentially across the full spectrum of gestational age. Specifically, verbal skills moderated the association between gestational age and symbolic number performance (cardinality). The relation between verbal and cardinality skills were stronger at higher gestational ages compared to lower. Additionally, at higher gestational ages, children more frequently used retrieval strategy and less often relied solely on finger counting for the cardinality task. Shifting the focus from group differences to understanding individuals and their unique developmental pathways may enhance our insight into the risk and protective factors underlying the variability observed in all children.

Keywords

preterm-birth; numerical cognition; verbal skills; visuo-spatial skills

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Introduction

Children's numerical development requires the integration of multiple earlier-developing, complex set of skills. Early numerical development in children does not unfold independently from the development of other cognitive skills. A rich body of work highlights the unique and significant contributions of verbal and non-verbal skills to individual differences in numerical cognition (e.g., Ansari & Karmiloff-Smith, 2002; Dehaene & Cohen, 1995; Lefevre et al., 2010; Purpura & Reid, 2016; Verdine et al., 2014). The existing literature primarily focuses on group-level, but the nature of the associations between verbal and non-verbal systems and numerical cognition might vary based on multiple moderators, including the unique characteristics that children bring to numerical learning. As the developmental cascades approach states (Oakes & Rakison, 2019), there may be several obvious and non-obvious pathways behind individual children's numerical development trajectories.

To better delineate these unique patterns, the current study focused on the relation of verbal and non-verbal skills to numerical development in preterm-born children (PTB; < 37 weeks of gestation). Approximately, 15 million children worldwide are born preterm every year. In the United States, one out of every 10 babies are born preterm, and the incidence is on the rise (Martin et al., 2019; Martin & Osterman, 2024). PTB children show greater variability in their verbal and non-verbal skills compared to term-born (TB; ≥ 37 weeks gestational age) children. As a group, PTB children also perform lower than their peers in numerical cognition (Simms, Gilmore, et al., 2013). These difficulties predict important life outcomes. Math skills, sometimes more than literacy skills, predict school success, health, and lifetime earnings (Ritchie & Bates, 2013). For PTB children, the relationship between preterm birth and low adult wealth is mediated by numerical skills during middle childhood (Basten et al., 2015). Less is known about the origins of the PTB children's difficulties and sources of within-group variability that emerge even before children enter formal schooling. The connection between different domains might also be more pronounced in children with atypical developmental trajectories compared to typically developing children (Karmiloff-Smith, 2009). This paper aimed to a) examine early numerical skills of TB and PTB children across the entire range of gestational age, and b) pinpoint whether verbal and non-verbal skills play the same or different roles in explaining between- and within-group variability in TB and PTB children's numerical development.

Contribution of verbal and non-verbal skills to numerical development.

Verbal and non-verbal systems significantly contribute to individual differences in numerical cognition. For example, according to LeFevre's Pathways Model (Lefevre et al., 2010), there are three specific pathways by which children typically acquire early numeracy knowledge: linguistic (Hooper, Roberts, Sideris, Burchinal, & Zeisel, 2010; Juel, 1988), non-verbal/spatial functioning (McClelland, Acock, & Morrison, 2006), and quantitative (Dehaene & Cohen, 1995; Feigenson et al., 2013). This perspective aligns with neurocognitive models as well. The Triple Code Model (Dehaene & Cohen, 1995, 1997) states that three distinct neural circuits for numerical cognition underlie verbal, non-verbal/visuo-spatial, and internal quantity representations of numeric information. Empirical evidence supports

these theoretical frameworks, as relations between non-verbal skills and numerical skills have been firmly established in preschoolers, school-age children, and adults (Ansari et al., 2003; Cheng & Mix, 2014; Gunderson et al., 2012; Hegarty & Kozhevnikov, 1999; Laski et al., 2013; Verdine et al., 2014). In the preschool and early elementary school years, children's verbal and numeracy skills are also highly correlated (Hooper et al., 2010; Purpura, Hume, Sims, & Lonigan, 2011; Purpura & Ganley, 2014). Evidence from neuroimaging studies similarly shows substantial overlap between the neural basis of verbal processing and numerical processing in school-aged children (Baldo & Dronkers, 2007). Although a broad set of domain-general factors contributes to numerical development, such as working memory or executive function, it is important to highlight that verbal and nonverbal skills can predict later math outcomes, even after controlling for such general cognitive factors (e.g., Peng et al., 2020).

Previous literature suggests that various numerical skills are differentially predicted by different cognitive skills. For example, according to the Pathways Model, verbal skills are considered to more strongly predict children's performance on measures that involve knowledge of symbolic number systems (Lefevre et al., 2010). This is primarily because the mechanisms that underlie learning the symbolic number system are like mechanisms that underlie learning other symbolic systems, such as language. Non-verbal skills contribute to both symbolic numerical abilities as well as children's ability to operate on quantities, including non-verbal magnitude comparisons (Newcombe et al., 2019; Verdine et al., 2014). Here, we specifically focused on two basic symbolic numerical skills that provide the foundation for later mathematics success—rote counting and cardinality principle—which is collectively referred to as number word knowledge (Duncan et al., 2007; Geary et al., 2018). Focusing on early number word knowledge is crucial, as counting and cardinality predict math achievement in later school years (Nguyen et al., 2016). Number word knowledge is a subset of early numeracy skills that develop during the preschool years. Early numerical knowledge involves various other interconnected symbolic and nonsymbolic skills, including knowing number symbols (identification), recognizing quantities without counting (subitizing), understanding number patterns, understanding sequence of numbers (ordinality), estimation, and comparing and manipulating numerical magnitudes (Jordan & Levine, 2009; Merkley & Ansari, 2016).

Early numerical development in term-born children.

Rote counting, which is characterized as the ability to recite number words forward and backward, begins to develop around two years of age. Rote counting is a core number skill, and it lays the foundation for exact enumeration of quantities larger than five and helps develop calculation later in life, which strongly predicts later arithmetic skills (Koponen et al., 2013). Although children start reciting the count list around two years of age, comprehending the meanings of these words has an extended developmental trajectory (e.g., Carey, 2009; Wynn, 1992). Children spend several months learning the meaning of the number word “one,” before they learn what “two,” “three,” or “four” means. Children eventually grasp the cardinality principle—that the last number reached while counting a set represents the set's cardinal value—almost one to two years after children learn the count list (Gallistel & Gelman, 1990). The cardinal meanings of number words are learned

sequentially, one at a time (Wynn, 1990; 1992). Stated differently, when children understand the cardinal meaning of one number, they only grasp the cardinalities of smaller numbers, not those of larger ones until five (Sarnecka & Lee, 2009). Children typically acquire the meanings of “five” and higher words simultaneously. Understanding of the cardinal principle is tied to grasping the successor function—the concept that if a numeral in the count list represents the cardinality N , then the next numeral in the list will represent cardinality $N + 1$ (Merkley & Ansari, 2016). Although the stages children take are overall similar, the trajectories they exhibit in understanding the true meaning of number words are highly variable. For example, some children already understand the cardinal meaning of number words up to “four” and beyond by four years of age, whereas others at the same age have not mastered the meaning of the word “one” (Klibanoff et al., 2006). This variability is imperative because children’s number knowledge by kindergarten entry predicts their future achievement in mathematics (Duncan et al., 2007).

Verbal and non-verbal skills significantly contribute to the basic numerical skills of counting and cardinality. For example, preschool children, at the earliest stages of learning the cardinal meanings of the count words (i.e., “one,” “two,” “three”), appear to map these words onto an object-based representation system that can hold up to three or four items in memory (Carey, 2009). Children who develop proficient non-verbal representations of numbers earlier may leverage these representations to learn other numerical concepts, such as place value (e.g., Mix et al., 2016). Indeed, prior research shows that non-verbal reasoning predicts counting skills, which, in turn, is related to later arithmetic skills (Krajewski & Schneider, 2009). Counting is primarily a verbal skill. For instance, children with specific language impairments show significant deficits in the production of the count word sequence and basic calculation (Ansari et al., 2003). Cardinality also has strong ties to verbal systems; children’s understanding of cardinal numbers is related to their overall vocabulary size and the grammatical number system of their native language (Negen & Sarnecka, 2012). The existing literature primarily considers correlations between different systems at the group level. As a result, little is known about whether the nature of the relation between verbal and non-verbal systems and numerical cognition might vary based on, or be moderated by, the unique characteristics that children bring to numerical learning. Here, we examined the role of verbal and non-verbal systems in the basic numerical development of TB and PTB children and explored whether the relation between these systems and numerical performance differs between TB and PTB children.

Early numerical development in preterm-born children.

Children who are born preterm tend to fall behind in neurocognitive development (Guarini et al., 2014; Lipkind et al., 2012; Simms, Cragg, et al., 2013), and are at a higher risk of encountering mathematical difficulties once they reach school age (Lipkind et al., 2012; Quigley et al., 2012). Although PTB children generally face academic challenges, difficulties in mathematics are particularly pronounced (Simms et al., 2013). However, not all PTB children fall behind—some progress to have favorable developmental trajectories for numerical cognition. To better understand the developmental origins and nature of numerical difficulties, it is important to investigate how skills that predict mathematics performance in TB children contribute to the numerical development of PTB children.

Prior literature explored the contribution of verbal and non-verbal skills to both overall mathematical performance as well as more basic numerical skills in PTB children (Adrian et al., 2020; Simms, Cragg, et al., 2013; Simms et al., 2015). However, the existing work primarily focused on children at, or after, the start of formal schooling, and the primary emphasis has been on very PTB children (< 32 weeks of gestation) (Guarini et al., 2014; Simms et al., 2015; Simms, Gilmore, et al., 2013). This body of work showed that verbal and non-verbal skills significantly contribute to PTB children's mathematical development (Johnson et al., 2011a). In elementary school children, verbal and non-verbal skills emerge as more important predictors of between-group variability in PTB and TB children, compared to other domain-general factors, such as executive function or attentional skills (Simms et al., 2013). Verbal and non-verbal skills also predict greater variance in PTB children's later mathematical outcomes than in TB children's outcomes in school age children (Simms et al., 2012). In younger kindergarten-age children, verbal and non-verbal abilities similarly significantly predict math skill in very PTB children, again even after controlling for other domain-general functions such as executive function (Adrian et al., 2020; Hasler & Akshoomoff, 2019). Prior literature more frequently reported the contribution of non-verbal skills in these early ages. Specifically, for basic numerical skills such as counting, non-verbal skills (e.g., Adrian et al., 2020; Clayton et al. 2022; Simms et al., 2015) have been shown to mediate preterm birth-related group differences. A recent but smaller literature reported the mediating role of verbal skills as well (Adrian et al., 2020).

These results are informative in highlighting how verbal and non-verbal skills might explain within-group differences (i.e., mediate the role of preterm birth on numerical skills). However, less is known about whether verbal and non-verbal skills differentially predict within-group differences. Stated differently, does preterm birth moderate the associations of verbal and non-verbal skills to numerical performance? In line with the developmental cascades approach (Oakes & Rakison, 2019), there may be several obvious and non-obvious pathways behind individual children's numerical development trajectories. Further, associations between different domains might be more noticeable for children who follow atypical developmental trajectories than typically developing children (Karmiloff-Smith, 2009).

Preterm-born children represent an optimal window into the nature and sources of variability in the interrelations among verbal, non-verbal, and numerical cognition. Comparing sources of within-group variability in TB versus PTB children might give insight into component skills that children recruit for learning. If the profiles of associations are similar in the two groups, this would suggest a common set of mechanisms underlying learning in PTB and TB children. If the associations differ, this would suggest that there might be multiple possible routes to learning that vary across PTB and TB children. Following precision developmental science approach, the focus on understanding individuals and their unique cascading developmental pathways might enhance our understanding of risk and protective factors that predict the variability observed in PTB children (Demir-Lira & Göksun, 2024). It is also important to reiterate that the existing research on PTB's numerical development primarily focused on children at or after the onset of formal schooling, and those born very preterm. The foundation of later differences in numerical performance is established during the preschool years. Therefore, identifying the sources of difficulty during the preschool

years is crucial for early detection and intervention, which can enhance school success, particularly for at-risk children. Extending results to the full spectrum of gestational age will provide a more complete picture of the role of preterm birth on numerical development.

Current study.

Our overall goal was to pinpoint the relation between verbal and nonverbal skills to children's early numerical performance during the preschool years, where foundational numerical skills are acquired. We examined how verbal and non-verbal skills predicted between- and within-group variability in early numerical skills of PTB and TB children. In doing so, we aimed to extend the prior literature in two significant ways. First, we examined the early numerical skills of children across the entire range of gestational age. Prior emphasis has been on very PTB children (< 32 weeks of gestation). This focus overlooks the majority of PTB children—those born moderate-to-late preterm (33–36 weeks of gestation), which constitute the majority (75%) and fastest growing group of all PTB children (Loftin et al., 2010). Moderate-to-late PTB children also have a risk of math difficulties, and due to their higher numbers, they represent a higher percentage of children with academic difficulties than the very PTB children (Chyi et al., 2008). Given the mixed approaches in the literature, we ran analyses using gestational age as a continuous variable, as well as using three categories of gestational age (very, moderate-to-late, term). Second, we focused on the building blocks of numerical cognition—counting and cardinality (Ryoo et al., 2015). Existing studies primarily focused on later-developing aspects of mathematical performance in elementary school children. However, differences in children's numerical skills are present even before school entrance and differences at school entrance have significant long-term implications (Duncan et al., 2007). To fill the knowledge gaps in the literature, we asked two central questions:

1) How does gestational age relate to children's basic numerical and arithmetic skills?—Based on prior literature (Chyi et al., 2008; Simms et al., 2015), we hypothesized that children with lower gestational ages would exhibit poorer numerical performance. Although there is limited data on mathematical development specifically, drawing from the literature on general academic performance (Chan et al., 2016), we predicted moderate-to-late PTB children to perform lower than their TB peers, yet better than their very PTB peers.

2) Do verbal and non-verbal skills play differential roles in predicting outcomes as a function of preterm birth?—Little is known about whether verbal and non-verbal skills play differential roles in explaining within-group variability across different gestational age groups. Given theoretical suggestions that relations between different performance domains may vary for typically developing versus atypically developing children (Karmiloff-Smith, 2009; Oakes & Rakison, 2019), we expected a significant moderation. However, we did not have a specific prediction regarding whether gestational age would moderate the impact of verbal or non-verbal skills on children's numerical outcomes.

Method

Participants

Participants included a total of 197 three- to five-year-old PTB and TB children. This study was part of a larger project on cognitive development of PTB and TB children with multiple measures (see Nelson et al., 2021 for information on other measures). We considered gestational age both continuously and as a categorical variable. For the categorical variable, participants were divided into three groups based on gestational age: Very PTB children included those born 32 weeks or less of gestation ($n=40$), moderate-to-late PTB children included those born between 33 and 36 weeks of gestation ($n=53$), and TB children included those born 37 weeks of gestation or after ($n=104$) (Loftin et al., 2010). Participants were recruited using the university hospital's electronic health records, university mass emailing, social media, and word of mouth. Children were eligible for this study if they were between three-to-five years of age, were native speakers of English, had normal or corrected-to-normal vision and hearing, had no history of a genetic syndrome or birth defect, and had no limitations (based on parental report) that would prevent them from completing paper/pencil tasks. For families who completed the study in an online format, it was also preferred that they had an electronic device (computer, laptop, tablet, or smart phone) with reliable internet. Parent-child dyads without an electronic device were mailed an Amazon Fire tablet that they could use to participate in the online sessions. This study was approved by the local Institutional Review Board.

Face-to-face and online parent-child dyads did not significantly differ in child age, child gender, ethnicity, race, gestational age, parent education, or household income. Children and parents were predominately White and from high-socioeconomic backgrounds, with an average household income of \$126,494.71, and an average parent education corresponding to a college degree. There was considerable variability in education levels, ranging from a high school degree to an advanced degree, and in income, which ranged from \$14,000 to \$700,000. The sample also included participants from both urban and rural areas. Table 1 presents demographic information for the three gestational age groups. The three groups did not differ from each other on family income, $F(2,186)=0.127$, $p=0.880$. As expected, the three groups did differ in gestational age, $F(2,194)=614$, $p<0.001$. There was also a significant effect of group on child age at test, $F(2,191)=5.19$, $p=0.012$, and parent education, $F(2,194)=6.21$, $p=0.002$. Consistent with prior literature, very PTB children had overall lower parental education than TB children ($p=0.002$), but the two PTB groups did not differ from each other. Child age at test and parent education were included as covariates in the analyses below.

Procedure

For the in-person portion of this study, parent-child dyads attended a 3-hour laboratory visit. During this visit, experimenters administered the tasks to the children while the parents completed questionnaires about their child on a computer in another room. Tasks were administered in blocks, and children took breaks in between each block to address possible fatigue. For the online portion of the study, parent-child dyads completed four-45-minute sessions via Zoom during which the child completed the same tasks, and the parent was

asked to complete the questionnaires on their own time between the four sessions. Using feedback from a focus group with local parents who expressed concern regarding possible screen fatigue, we structured the online portion of the study across four, shorter online sessions rather than one 3-hour session. The order of the tasks was the same in both the face-to-face and online sessions, and the tasks were administered by the same research assistants. 75 completed the study face-to-face in a lab-based format and 122 completed the study in an online format via Zoom video conferencing (due to COVID-19-related restrictions in human research) (please see Nelson et al., 2021 for more information on the different data collection formats). Children's performance on some of the measures varied as a function of format, although the differences did not reach the conventional threshold for significance (Counting, $F(1,191)=2.85$, $p=0.093$, $\eta^2p=0.015$, WOC 5, $F(1,191)=3.47$, $p=0.064$, $\eta^2p=0.018$, WPPSI-IV Matrix Reasoning $F(1,191)=3.70$, $p=0.056$, $\eta^2p=0.19$). Based on these differences and because format served as an indicator for any possible cohort effects due to COVID-19 pandemic in children's development, format was included as a covariate in analyses.

Numerical Measures

Counting.—Children were asked to start at 1 and count to 20, and the highest consecutive number they correctly counted was noted. This measure can be conceptualized as a measure of children's knowledge of count sequence.

What's on this card (WOC).—Several measures have been used to assess children's cardinality principle, including the Point-to-X task (Wynn, 1992), What's on this Card (WOC) task (Gelman, 1993), and Give-A Number Task (Wynn, 1990, 1992). As part of this study, we used the WOC task. Importantly, children's performance on the WOC and Give-A Number task are highly consistent (LeCorre et al., 2006; Le Corre & Carey, 2007). Following the prior literature (Levine et al., 2010), in the WOC task, children were first shown a card with a single object on it and asked "What's on this card?". After the child named the object, the experimenter responded by saying "That's right, there's one [object]". This was to ensure that the children provided a cardinality response. During the rest of the task, children were shown a series of cards consisting of 1 to 9 objects, and prompted, "What's on this card?" asking to provide a response. Experimenters scored the total amount of cards the participant responded correctly to, out of a total of seventeen. Given that set size is a critical variable in the development of cardinal knowledge because small and large sets are thought to be represented by different underlying systems (e.g., Carey, 2009), trials were divided into two groups: easy trials (WOC 4) included 4 or fewer objects versus difficult trials (WOC 5) included 5 or more objects. The proportion of easy and difficult trials were used as the final score and the possible range was 0% to 100%. The internal consistency of the test was assessed using Cronbach's alpha, which yielded a value of 0.816, indicating good reliability.

WOC Strategy Coding.—To gain a better understanding of the systems children rely on, we coded the different strategies children used for each of the items on the WOC task based on video recordings of the session. Children's strategies were divided into 4 categories. *Retrieval strategy* consisted of answers where children simply verbally stated

the number of items on the card. *Counting strategy* consisted of answers where children counted the objects on the card and then provided an answer. *Counting with fingers strategy* referred to cases where children verbally counted the objects while also using their fingers to count. *Using fingers only strategy* referred to cases where children only used fingers to point to objects, without counting them out loud and providing an answer. For each item, the strategy children used was marked. However, video recordings were not set up with this question in mind and the video data enabling us to clearly code finger use was available only for a subset of the sample; we were able to code the strategies of 143 children from the full sample (79 TB, 37 moderate-to-late PTB, 27 very PTB). To ensure that the sample for the strategy coding was representative of the larger sample in the study, we confirmed that missing data of strategy coding was not significantly related to gestational age, $t(195)=0.980$, $p=0.328$, child age $t(195)=0.105$, $p=0.916$, or parental education, $t(195)=1.575$, $p=0.117$.

Verbal and Non-verbal Measures

Wechsler Preschool & Primary Scale of Intelligence-IV (WPPSI-IV) Information.

—Children were administered the Information subtest, part of the WPPSI-IV Verbal Comprehension Index, which measures children’s acquired verbal knowledge and is one component of verbal IQ. The Information subtest asks children about several facts (e.g., “what is a [blank] used for?”) (Wechsler, 2012). Raw scores were used as final scores for analysis, with a possible range of 0 to 31. For Information subtest specifically, the internal consistency is .89 and test-retest stability is .83.

Wechsler Preschool & Primary Scale of Intelligence-IV (WPPSI-IV) Matrix Reasoning.

—Children were administered the Matrix Reasoning subtest, part of the WPPSI-IV Fluid Reasoning Index, which measures children’s nonverbal visual processing and spatial perception skills. The Matrix Reasoning subtest asks children to select a missing portion from a matrix (Wechsler, 2012). Raw scores were used as final scores for analysis, with a possible range of 0 to 32. WPPSI-IV demonstrates excellent psychometric properties, including good internal consistency (.75 to .90), test-retest reliability (.75 to .87), interrater reliability (.96 to .99), and content validity (Syeda & Climie, 2014). For Matrix Reasoning subtest specifically, the internal consistency is .90 and test-retest stability is .82.

Results

Gestational age-related group differences on verbal, non-verbal, and numerical skills.

To address our questions, we first examined the role of gestational age on children’s verbal, non-verbal skills, and numerical outcomes. We ran general linear models utilizing gestational age as a continuous variable, and we confirmed these analyses using gestational age as a categorical variable. In all models, we included parental education, child age, and format as covariates. Table 2 represents the descriptive statistics for all measures as a function of gestational age group.

We first examined the role of gestational age on children’s verbal skills. Controlling for parent education, child age, and format, we found a main effect of gestational age on

WPPSI-IV Information scores, $B = 0.191$, $SE = 0.051$, $t(191) = 3.782$, $p < .001$, 95% CI [0.091, 0.291], with a standardized coefficient of $\beta = 0.256$. In this model, parent education also emerged as a significant predictor, $B = 0.460$, $\beta = 0.154$, $SE = 0.195$, $t(191) = 2.353$, $p = 0.020$, 95% CI [0.074, 0.845], as well as child age, $B = 1.862$, $\beta = 0.283$, $SE = 0.441$, $t(191) = 4.224$, $p < .001$, 95% CI [0.993, 2.732]. Format did not predict performance on WPPSI-IV Information ($p = 0.572$). These results were confirmed with analyses considering gestational age as a categorical variable (very PTB, moderate-to-late PTB, TB children), $p < 0.001$. Bonferroni corrected post-hoc analyses showed that TB children performed better than their very PTB ($B = -2.287$, $\beta = -0.662$, $SE = 0.610$, $t(190) = -3.750$, $p < .001$, 95% CI [-3.490, -1.084]) and moderate-to-late PTB peers ($B = -1.139$, $\beta = -0.329$, $SE = 0.543$, $t(190) = -2.098$, $p = 0.037$, 95% CI [-2.208, -0.068]). Very and moderate-to-late PTB children did not differ from each other on performance ($p = 0.078$).

There was no main effect of gestational age on WPPSI Matrix Reasoning scores, $B = 0.121$, $SE = 0.081$, $t(191) = 1.490$, $p = 0.138$, 95% CI [-0.039, 0.281], with a standardized coefficient of $\beta = 0.098$. In this model, only child age emerged as a significant predictor, $B = 5.189$, $SE = 0.708$, $t(191) = 7.331$, $p < .001$, 95% CI [3.793, 6.585], with a standardized coefficient of $\beta = 0.478$, whereas no other variables emerged as significant predictors (all p 's $> .30$). Results were confirmed considering gestational age as a categorical variable, $p = 0.684$.

We next examined the role of gestational age on the numerical measures, starting with counting. Children overall performed well on the counting task ($M = 17.4$). There was no main effect of gestational age on counting, $B = 0.007$, $\beta = 0.008$, $SE = 0.069$, $t(176) = 0.106$, $p = 0.915$, 95% CI [-0.1298, 0.145]. In this model parental education, $B = 0.66238$, $\beta = 0.163$, $SE = 0.2901$, $t(176) = 2.284$, $p = 0.024$, 95% CI [0.090, 1.235], and child age, $B = 2.797$, $\beta = 0.337$, $SE = 0.605$, $t(176) = 4.623$, $p < .001$, 95% CI [1.603, 3.991], emerged as significant positive predictors, whereas format did not ($p = 0.629$). The results, when considering gestational age as a categorical variable (very PTB, moderate-to-late PTB, TB children), did not show a significant effect either, $p = 0.447$.

We then examined differences in WOC 4. Overall, children performed well on this task with 98% average accuracy across the groups. There was no main effect of gestational age on WOC 4, $B = 0.001$, $\beta = 0.004$, $SE = 0.001$, $t(177) = 0.01$, $p = 0.996$, 95% CI [-0.003, 0.003]. Child age emerged as a significant predictor, $B = 0.026$, $\beta = 0.173$, $SE = 0.012$, $t(177) = 2.25$, $p = 0.026$, 95% CI [0.003, 0.049]. Parental education and format were not significant predictors (p 's > 0.10). The results were confirmed with analyses considering gestational age as a categorical variable (very PTB, moderate-to-late PTB, TB children), $p = 0.898$.

Next, we examined differences in WOC 5. There was a main effect of gestational age on WOC 5, $B = 0.010$, $\beta = 0.180$, $SE = 0.004$, $t(177) = 2.54$, $p = 0.012$, 95% CI [0.002, 0.018]. Format, $B = 0.091$, $\beta = 0.351$, $SE = 0.0364$, $t(177) = 2.50$, $p = 0.013$, 95% CI [0.019, 0.163], and child age, $B = 0.191$, $\beta = 0.388$, $SE = 0.034$, $t(177) = 5.53$, $p < .001$, 95% CI [0.123, 0.260] also emerged as significant predictors. Parental education was not a significant predictor ($p = 0.831$). The results were confirmed with analyses considering

gestational age as a categorical variable (very PTB, moderate-to-late PTB, TB children), $p = 0.006$. Post-hoc analyses showed that TB children performed better than the very PTB group ($B = -0.154$, $\beta = -0.592$, $SE = 0.0482$, $t(176) = -3.19$, $p = 0.002$, 95% CI [-0.24889, -0.0587]). Moderate-to-late PTB children performed worse than TB children ($p = 0.095$) and better than very PTB children ($p = 0.108$), but these differences did not reach statistical significance.

Interim summary.—Gestational age emerged as a significant predictor of children’s verbal performance (WPPSI-IV Information) and difficult cardinality items (WOC 5), but not their non-verbal performance (WPPSI-IV Matrix Reasoning), counting, or performance on easy cardinality items (WOC 4). Given the unique associations between gestational age and children’s performance on difficult cardinality, we next asked whether the role of verbal and non-verbal skills in explaining the variability in children’s scores on this task varied as a function of gestational age.

Gestational age moderating the relation of verbal and non-verbal skills to numerical (cardinality) performance.

We asked whether gestational age moderated the association of verbal and non-verbal skills to child WOC 5 outcomes. We ran one moderation model in R version 4.2.2 (RStudio Team, 2022) via the *sem* function in the *lavaan* package (Yves, 2012). Format, child age, and parent education were entered as covariates. We created two interaction terms, where verbal and non-verbal skills were paired with gestational age (e.g., WPPSI-IV Information x gestational age). All variables were mean-centered. In this model, the interaction component between WPPSI-IV Information scores and gestational age was significant in predicting children’s WOC 5 performance, whereas the interaction with WPPSI-IV Matrix Reasoning was not significant (Table 3).

This interaction finding was confirmed with the Johnson-Neyman technique (Johnson & Neyman, 1936) and simple slopes analysis. In these analyses, we used gestational age as a continuous variable to determine the interval of gestational age where WPPSI-IV Information emerged as a significant predictor of WOC 5 performance. WPPSI-IV Information was related to WOC 5 when gestational age was above 35.22 weeks ($p < .05$, corrected for multiple comparisons). This partially corresponds to the cut-off between moderate-to-late PTB and TB when using the categories for gestational age. As depicted in Figure 2, the difference in the slopes for children with higher versus lower gestational age shows that gestational age moderated the relation between WPPSI-IV Information scores and children’s performance on WOC 5. The positive relation between verbal skill and children’s WOC 5 score was stronger for children with higher gestational ages. In Figure 2, relations are examined at three different levels of gestational age for visualization purposes only (1 standard deviation above the mean, mean, and 1 standard deviation below the mean). In other words, the higher the gestational age, the stronger the positive relation between verbal skills and children’s WOC 5. Importantly, when a corresponding Johnson-Neyman analysis was conducted for WPPSI-IV Matrix Reasoning, a gestational age above 21 weeks was found to be related to WOC 5 ($p < .05$, corrected for multiple comparisons),

suggesting that non-verbal skills are associated with WOC 5 across the gestational age spectrum.

Strategy analyses: Relation of strategy to preterm birth

Last, we asked whether the strategy children used varied as a function of gestational age. To address this question, we first examined the role of gestational age on children's strategies during the WOC task (retrieval, counting, counting and finger use, and finger use only). Specifically, the percent of items children used a given strategy was calculated. Overall, the most frequent strategy was retrieval ($M = 0.612$) followed by counting with fingers ($M = 0.280$), counting ($M = 0.062$) and counting with fingers only ($M = 0.042$).

We ran a sequence of general linear models with gestational age as a continuous variable. In all models, we included parental education, child age, and format as covariates. Gestational age did not predict the frequency of counting strategy or counting with fingers strategy (p 's > 0.30). However, gestational age was a significant predictor of retrieval and finger counting only. For retrieval, there was a main effect of gestational age, $B = 0.008$, $\beta = 0.165$, $SE = 0.004$, $t(139) = 1.955$, $p = 0.053$, 95% CI $[-0.0001, 0.016]$. The higher the gestational age, the higher the proportion of items children retrieved on the WOC task. In this model, age, $B = 0.109$, $\beta = 0.251$, $SE = 0.036$, $t(139) = 3.046$, $p = 0.003$, 95% CI $[0.038, 0.180]$, and format, $B = -0.086$, $\beta = -0.383$, $SE = 0.038$, $t(139) = -2.259$, $p = 0.025$, 95% CI $[-0.161, -0.011]$, also emerged as significant predictors. Older children and children who completed the study in the online format were more likely to retrieve.

Gestational age was also a negative predictor of finger counting only strategy, $B = -0.004$, $\beta = -0.178$, $SE = 0.002$, $t(139) = -2.115$, $p = 0.036$, 95% CI $[-0.008, -0.001]$. The lower the gestational age, the higher was the proportion of items on which children used finger counting only on the cardinality task. In this model, child age also emerged as a significant predictor, $B = 0.078$, $\beta = 0.411$, $SE = 0.016$, $t(139) = 4.974$, $p < 0.001$, 95% CI $[0.047, 0.109]$. Older children were more likely to use finger counting only than younger children.

Overall Summary.

Gestational age-related discrepancies were most pronounced on the verbal measure (WPPSI-IV Information) and the difficulty measure of cardinality (WOC 5 task). Verbal skills moderated the role of gestational age, with a stronger prediction of WOC 5 performance at higher gestational ages compared to lower ones. Finally, at higher gestational ages, retrieval strategies became more frequent, while the finger counting strategy was used less often.

Discussion

Our goal in this paper was to pinpoint the possible differential roles of verbal and non-verbal skills in the numerical performance of PTB versus TB children. We aimed to add to the existing literature by focusing on (1) the full spectrum of gestational age, (2) basic numerical skills during preschool years, and (3) examining the contribution of verbal and non-verbal skills to both between and within group variability.

Numerical skills vary with gestational age.

First, gestational age was related to some basic numerical skills, but not others. PTB children performed lower than their TB peers on more challenging cardinality items, but not on easier cardinality items or on counting. The prior emphasis has been on very PTB children, and our results confirm prior findings in the literature on the possible numerical difficulties in very PTB children (Adrian et al., 2020). We added to these findings by showing that differences are present even at the beginning of formal schooling, especially on more challenging numerical tasks, but not simpler tasks such as counting or small set cardinality. Notably, although the emphasis has been on very PTB children, we identified delays across the full spectrum of gestational age. On this spectrum, moderate-to-late PTB children form the largest and fastest growing group among all PTB children (Loftin et al., 2010). In our categorical analyses, moderate-to-late PTB children fell right in the middle of very PTB and TB children. Their performance was not significantly worse than of TB children, but they were also not significantly better than very PTB children. Overall, our results suggest that numerical difficulties are not limited to very PTB children, and it is important to identify early delays in children across the full spectrum of gestational age. This is consistent with other studies focusing on school performance (Chyi et al., 2008)

Why might children show specific difficulties on more difficult cardinality trials? Set size is considered to significantly influence the development of cardinality knowledge because small versus large sets are represented by two different systems (exact-number versus large-approximate number systems) (e.g., Carey, 2009). Children's understanding of small sets or small number words can be built upon pre-existing nonverbal representations that are present even during infancy. Wynn (1990, 1992) argued that performance on items smaller than 4 might not reflect a true understanding of cardinality, but instead might be related to perceptual subitizing systems. However, set sizes of 4 or greater have a more extended developmental trajectory. Thus, differences between PTB and TB children might have been most apparent on more challenging numerical tasks that truly tap into cardinality understanding. Further, in the current study, we focused on the period before school entrance. The variability in children's performance on these tasks was restricted, most children performed at ceiling on the counting and simple cardinality tasks. It is possible that group differences would have been more apparent in earlier years when children are first acquiring smaller numbers—especially with respect to the counting task. This is a possible limitation of the current study and highlights the need for more sensitive counting measures in future work.

Gestational age moderates the relation between verbal and numerical skills.

Second, we examined whether gestational age moderated the association of verbal skills to basic numerical skills, specifically cardinality. We first showed that both verbal and non-verbal skills predict children's numerical performance, consistent with the prior literature on the relations of verbal and non-verbal skills to verbal number skills in TB children (Johnson et al., 2011b; Simms, Cragg, et al., 2013; Simms et al., 2015; Simms, Gilmore, et al., 2013). Several researchers similarly suggest that various verbal skills, such as vocabulary skills and syntactic-semantic bootstrapping, could support number word learning (Negen & Sarnecka, 2012). Our results are also consistent with the literature suggesting that the

difficulties PTB children have might be due to domain-general factors, as opposed to difficulties in specific numerical representations (Simms, Cragg, et al., 2013a). For example, difficulties in PTB children experience are not fully explained by general neurocognitive delays, such as IQ (Simms et al., 2015; Taylor et al., 2009) and in adults (Aarnoudse-Moens et al., 2009; Twilhaar et al., 2018). Further, although both school-aged PTB children and children with dyscalculia experience mathematical difficulties, PTB children's difficulties differ from those of children with dyscalculia who show imprecise numerical representations (Simms et al., 2015). Brain structures associated with mathematical performance do overlap in PTB children and children with dyscalculia, particularly in parietal regions, but there are also differences where prematurity-related associations are observed in frontal, parietal and temporal regions (Starke et al., 2013). Taken together, we extend prior findings in the literature by showing that the role of verbal and non-verbal skills is present in early preschool years for basic numerical tasks as well as for the full spectrum of gestational age.

We also showed that the role of verbal and non-verbal skills varies as a function of gestational age in explaining the within group variability in numerical performance. While both verbal and non-verbal skills were predictive of performance on difficult cardinality items, gestational age moderated the relation of verbal skills to numerical performance. That is, verbal skills predicted performance on difficult cardinality items to a greater extent at higher gestational ages compared to lower gestational ages—verbal skills played a more important role in predicting the variability in numerical skills of children with higher gestational ages. Why did we observe that verbal skills play a greater role for TB children in predicting cardinality performance, whereas we did not observe group differences for the role of non-verbal skills in predicting numerical skills across gestational age? PTB children in this sample performed lower than their peers in terms of their verbal performance, but not non-verbal performance. A growing body of literature highlights early emerging, specific, and persistent verbal difficulties in PTB children (Barre et al., 2011; Putnick et al., 2017). On the other hand, evidence on the effect of preterm birth on non-verbal skills is mixed; some report differences among PTB children, especially very PTB children (Simms et al., 2015; Taylor et al., 2009), whereas others do not (Clingan-Siverly et al., 2021). Yet, others observe differences on certain non-verbal tasks but not others (Adrian et al., 2020). Taken together, we argue that PTB children might rely on their relatively weaker verbal abilities to a lower extent in approaching basic numerical tasks than their TB peers—especially for symbolic numerical tasks. In contrast, TB children who have stronger verbal skills compared to PTB children might rely on their verbal skills to a greater extent than their PTB peers. This argument was supported by the differences we observed in the strategies children used. Retrieval strategies that heavily rely on verbal systems were more frequent at higher gestational ages, whereas using fingers only, which can be considered as a non-verbal strategy was more frequent at lower gestational ages. Overall, differential reliance on verbal versus non-verbal skills could be considered as adaptations children bring into numerical learning contexts as a function of their broader characteristics.

Differential routes to cardinality have been observed in another atypical population. For example, Ansari et al. (2003) examined number development in children with Williams syndrome, who present a profile opposite to the one observed for PTB children in the current paper. Williams Syndrome (WS) is characterized by relative strength in verbal skills

coupled with significant difficulties in numerical cognition. Interestingly, in this group of children, variance in cardinality understanding was associated with verbal skill, whereas in normal comparison non-verbal skills predicted the variance. The result for the typically developing group is seemingly inconsistent with the other we present here. However, neurotypical controls in this study were 3.5 years old, and non-verbal skills might play a greater role during these initial stages of learning (Brannon & Van de Walle, 2000; Uttel & Cohen, 2012). What is consistent for both groups of children with atypical developmental trajectories is that both groups leveraged their relatively stronger skill, greater reliance on stronger verbal for WS and lower reliance on weaker verbal for PTB children and perhaps greater use of non-verbal strategies, when acquiring numbers. Taken together, a focus on atypical populations reveals that there might be multiple possible routes to numerical development that vary depending on children's characteristics.

Although the differential patterns could be considered as adaptations, PTB children did perform lower than their peers in their difficult cardinality items. Thus, the differential reliance on verbal versus non-verbal systems for basic numerical tasks was associated with different behavioral performance. Some argue that non-verbal skills might be more important when individuals first acquire a skill and they become less integral once individuals master this new content (Uttal & Cohen, 2012). According to this developmental cycling approach, non-verbal skills might be more predictive of numerical skills when skills are newly introduced or still challenging (Mix et al., 2016). Thus, we might have observed non-verbal skills explaining preterm birth-related discrepancies in numerical development because PTB children are overall delayed in their numerical performance. This is broadly consistent with the symbolic estrangement hypothesis as well (Lyons et al., 2012a). According to symbolic estrangement, initially symbolic numbers, that are human inventions, might be more tightly linked to their associated nonsymbolic representations, which are processed even in nonverbal infants (Hyde et al., 2010; Xu et al., 2007). For example, children who are less proficient in numerical processing might be more reliant on this mapping between two formats. Over time, with increased proficiency and increased practice with symbolic numbers at home or in various educational settings, symbolic numbers might become estranged from nonsymbolic representations where children might become less reliant on the mapping between two representation formats (Lyons et al., 2012b). Here, we only focused on symbolic number processing, but the fact that symbolic number processing was more strongly tied to verbal performance in TB children compared to PTB children is overall consistent with this view. Thus, differential reliance on verbal versus non-verbal systems might be due to performance differences as well. Taken together, when considered at a single point in time, PTB children and their TB peers might perform differently at a given task, it is important to examine longitudinal patterns. Longitudinal studies examining changing relations of verbal and non-verbal skills to numerical development are needed to examine whether the differential roles of verbal and non-verbal skills in PTB children indicate adaptations or delays.

We also argue that our pattern of results is consistent with the Pathways Model (Lefevre et al., 2010) where verbal skills are considered to strongly predict children's performance on measures that involve knowledge of symbolic number systems. Our results could be explained using a verbal cascades model (Demir-Lira, in preparation). According to

this model, the development of early verbal skills might have downstream, cascading effects on children's symbolic numerical development, especially in children with different environmental and biological risk factors. Over time, as children become more familiar with symbolic numbers, for children with stronger verbal skills, symbolic number might become more tightly linked to verbal representations. It is possible that children who have stronger verbal skills have an easier time switching to representing symbolic numbers devoid of their nonverbal representations. Consistent with this view, for example, preschoolers from disadvantaged socioeconomic status (SES) backgrounds perform at a level that is similar to their peers when experimenters provide non-verbal support to solve simple arithmetic problems but lag behind when presented with verbal information only (Jordan et al., 1994). This could partially be due to the stronger verbal skills that are especially associated with SES, with differences emerging as early as the second year of life, at least in the US (Fernald et al., 2013; Noble et al., 2015). Although this is a hypothesis that remains to be tested, our results are consistent with this interpretation. Overall, our findings suggest that the far-reaching relations between preterm birth and numerical outcomes, or any other cognitive outcome, might be due to other intermediary processes that affect the unfolding of numerical cognition.

Gestational age-related differences might be rooted in children's experiences in preschool or in the home. The home numeracy environment is a modifiable contributor to children's numerical development, but its role for PTB children remains unexplored (Mutaf-Yıldız et al., 2020). Early variability in children's numerical skills prior to formal schooling suggests possible influences from the home numeracy environment or from the preschool environment. In PTB children, prior research shows that parental socioeconomic status (SES) strongly predicts academic outcomes, even more so than biological factors such as obstetrical risk, and moderates the relation between prematurity and academic outcomes (Beauregard et al., 2018). In our study as well, parental education, a widely used correlate of SES, predicted variability in verbal skills for all children. A recent systematic review suggested that preterm-born children's verbal skills are indeed tied to a wide range of qualitative and quantitative features of parental stimulation at home (Nelson & Demir-Lira, 2023). Some argue that environment might play an even stronger role for PTB children (Belsky et al., 2007; Gueron-sela et al., 2015). To our knowledge, nothing is known about the role of specific home numeracy environment, numerical activities, talk about numbers, or preschool experiences for PTB children. It is possible that term children had richer experiences around numbers or more broadly richer input, specifically number talk, compared to PTB children, which in turn has cascading effects on their numerical skill. Future work should explore the relations of these experiences to children's early academic development across the full spectrum of gestational age. In the current project, we did not assess children's pre-reading skills which would have enabled us to test comorbidity between reading and numerical difficulties (Fletcher, 2005). Future studies should explore whether delays in numerical skills are specific or similar patterns are also observed for pre-reading skills. Given that we found that PTB children performed lower in their verbal skills and given the strong relations of verbal skills to pre-reading, one could expect delays in pre-reading as well.

Limitations.

Our study had certain limitations. While our sample was variable in education, income, and rurality, overall, the majority sample belonged to a higher SES group. Preterm birth is more prevalent among families from lower SES backgrounds; for instance, rates of preterm birth are linked to familial income levels (Blumenshine et al., 2011; Kramer et al., 2000; Parker et al., 1994). This highlights the importance of examining this topic in a more socioeconomically diverse sample. Second, we used single measures of verbal and non-verbal processing. Given the purposes of our study, we chose a spatial task measuring spatial visualization that has been shown to be among the most strongly related to mathematical skills (Mix et al., 2016). Spatial reasoning visualization is especially important for younger children, whereas other types of non-verbal skills, such as perspective-taking emerge as a strong predictor in later years of schooling (Hawes et al., 2019; Mix et al., 2016). We administered the WPPSI-IV Matrix Reasoning as our nonverbal measure. This subtest is broadly construed more specifically as a nonverbal reasoning measure, but it also involves spatial reasoning. Nonverbal reasoning, as measured by matrix reasoning and other measures of spatial skill substantially overlap (Colom et al., 2002; Lohman, 2000). When nonverbal reasoning, spatial and verbal skills are included in the same model, nonverbal skills predict later outcomes to predict children's later mathematics outcomes over and above others (Green et al., 2017). Our verbal measure was the WPPSI-IV Information subtest, which is a composite measure. It is broadly construed as one component of verbal IQ, one that is likely particularly influenced by environmental exposure. Composite measures of verbal skill are indeed particularly strong predictors of children's numerical skills (compared to specific skills, such as phonological processing), after controlling for other domain general factors, such as working memory or executive function (Peng et al., 2020). Although our results provide evidence for the differential contribution of verbal skills to numerical cognition, future work should examine multiple measures of verbal and non-verbal skills. Future work should separate nonverbal reasoning from more canonical measures of spatial ability as well as unpack verbal ability to its components (i.e. verbal reasoning, vocabulary, relational language), to see if differential relations are also observed for a broader set of measures.

Though our data suggests differential relations, we cannot establish causality from verbal and non-verbal tasks to numerical processing. The cross-sectional data we provide here should form the basis of future research such as longitudinal designs or intervention studies to test the causal role of verbal and non-verbal skills. Finally, our inclusion/exclusion criteria precluded children who had certain risk factors; thus, we included a relatively homogenous PTB sample. Medical risk factors, such as hospital length or neonatal morbidities, are predictive of child outcomes (Johnson et al., 2011a; Twilhaar et al., 2018), and thus our results should be replicated with a sample with more variable medical risk profiles. Further, studying these aspects of children's lives in a higher SES and less medically homogenous sample may have allowed us to examine these complex relations with less influence from some notable confounds (e.g., nutritional differences, sleep, extreme motor difficulties).

Taken together, to our knowledge, this was the first study to examine the sources of individual variability in children's numerical profiles across the full spectrum of gestational age before entrance to formal schooling. We showed that PTB preschoolers are at a

risk of falling behind on certain numerical tasks, but not others. We also highlighted the differential contributions of verbal and non-verbal skills to children's numerical performance in PTB versus TB children. Moving beyond group differences, the focus on understanding individuals and their unique cascading developmental pathways might enhance our understanding of risk and protective factors that predict the variability observed in PTB children.

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Highlights

- Gestational age is positively correlated with better verbal skill, but not nonverbal skill.
- Gestational age is positively correlated with performance on difficulty cardinality items.
- Verbal skills differentially relate to numerical skills across gestational age.
- Relations between verbal and numerical skills are stronger at higher gestational ages.
- Children with higher gestational age use retrieval strategy more frequently than peers with lower gestational age.

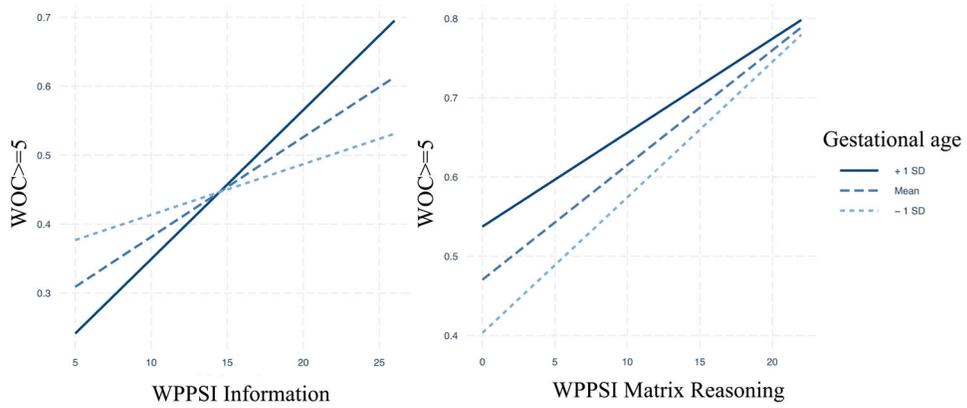


Figure 2. Interaction effects between WPPSI Information and Matrix Reasoning scores and gestational age on the WOC ≥ 5 . a. For visualization purposes only, the lines represent the simulated slopes for the relationship between WPPSI subtests and WOC ≥ 5 under different conditions of gestational age (solid for 1 standard deviation above the mean, dashed for the mean, and dotted for 1 standard deviation below the mean).

Table 1.

Demographic Information for all Participants (N=197)

Variable	<i>M (SD) or n (%)</i>		
	Very PTB	Moderate-to-Late PTB	Term
Child Age (years)	4.79 (0.56)	4.82 (0.49)	5.05 (0.52)
<i>Child Gender</i>			
Female	21 (52.5%)	25 (47.2%)	50 (48.1%)
Child Not Hispanic or Latino	38 (95%)	52 (98.1%)	97 (96%)
Child White	37 (92.5%)	50 (94.3%)	97 (95.1%)
Gestational Age	28.3 (3.03)	34.8 (1.06)	39.4 (1.24)
Household Income (USD)	\$132,125 (\$120,559)	\$121,882 (\$91,672)	\$126,756 (\$84,629)
<i>Parent Education</i>			
High school	4 (10%)	1 (1.9%)	4 (3.8%)
Some college credit	8 (20.0%)	6 (11.3%)	6 (5.8%)
Associate's Degree	4 (10%)	9 (17.0%)	7 (6.7%)
Bachelor's Degree	13 (32.5%)	19 (35.8%)	35 (33.7%)
Professional Degree	11 (27.5%)	18 (34.0%)	52 (50%)

Table 2.

Descriptive Statistics for Verbal, Non-verbal and Numerical measures.

Variable	<i>M (SD)</i> <i>Range</i>		
	Very PTB	Moderate-to-Late PTB	TB
Verbal			
WPPSI Information*			
Raw	17.8 (4.48) 5-25	19.1 (3.40) 9-26	20.8 (2.59) 14-26
Scaled	9.42 (3.50) 1-18	10.4 (3.07) 2-17	11.8 (2.93) 4-22
Non-verbal			
WPPSI Matrix Reasoning			
Raw	10.1 (4.98) 1-21	10.6 (5.56) 0-20	12.2 (5.94) 0-22
Scaled	9.58 (3.25) 3-16	9.67 (3.74) 1-16	110.4 (4.03) 0-17
Numerical			
Counting	16.2 (5.14) 0 - 20	16.8 (4.89) 4 - 20	18 (3.66) 1 - 20
WOC 4	0.98 (0.07) 0.75 - 1	0.98 (0.04) 0.88 - 1	0.98 (0.09) 0.25 - 1
WOC 5*	0.67 (0.23) 0 - 1	0.78 (0.24) 0 - 1	0.81 (0.23) 0 - 1

Note. Measures where group differences were observed are marked with an asterisk.

Table 3.

Moderation Analyses for Predictors of WOC 5.

Predictor	Estimate	Std. Error	z	p-value	95% CI Lower	95% CI Upper
Child age	0.082	0.038	2.177	0.030*	0.008	0.155
Parent education	-0.002	0.015	-0.139	0.889	-0.032	0.028
Format	0.101	0.034	2.954	0.003*	0.034	0.168
Gestational age	0.027	0.018	1.506	0.132	-0.008	0.062
WPPSI-IV Information	0.057	0.02	2.83	0.005*	0.018	0.097
WPPSI-IV Matrix Reasoning	0.08	0.019	4.118	<0.001*	0.042	0.118
	0.039	0.017	2.34	0.019*	0.006	0.071
WPPSI-IV Information X Gestational Age						
WPPSI-IV Matrix Reasoning X Gestational Age	-0.027	0.02	-1.359	0.174	-0.066	0.012
Residual variance	0.045	0.005	9.566	0.000	0.036	0.054