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Full-Term Children with Lower Vocabulary Scores Receive More Multimodal Math Input Than Preterm Children

Dilay Z. Karadöller[a,b,c], Ö. Ece Demir-Lira[d], and Tilbe Göksun[a]

[a]Koç University, Turkey; [b]Middle East Technical University, Turkey; [c]Max Planck Institute for Psycholinguistics, the Netherlands; [d]University of Iowa, USA

ABSTRACT

One of the earliest sources of mathematical input arises in dyadic parent–child interactions. However, the emphasis has been on parental input only in speech and how input varies across different environmental and child-specific factors remains largely unexplored. Here, we investigated the relationship among parental math input modality and type, children's gestational status (being preterm vs. full-term born), and vocabulary development. Using book-reading as a medium for parental math input in dyadic interaction, we coded specific math input elicited by Turkish-speaking parents and their 26-month-old children ($N = 58$, 24 preterms) for speech-only and multimodal (speech and gestures combined) input. Results showed that multimodal math input, as opposed to speech-only math input, was uniquely associated with gestational status, expressive vocabulary, and the interaction between the two. Full-term children with lower expressive vocabulary scores received more multimodal input compared to their preterm peers. However, there was no association between expressive vocabulary and multimodal math input for preterm children. Moreover, cardinality was the most frequent type for both speech-only and multimodal input. These findings suggest that the specific type of multimodal math input can be produced as a function of children's gestational status and vocabulary development.

Numerical understanding is one of the foundational human cognitive capacities that young children need to develop to function successfully in the world (Carey & Barner, 2019). Success in math is important in that higher math skills predict greater school success, wealth, health, and life satisfaction (e.g., Claessens & Engel, 2013; Duncan et al., 2007; Peters, 2020; Ritchie & Bates, 2013; Rittle-Johnson et al., 2017). Several factors are associated with numerical development (Levine et al., 2010). These may stem from child- and environment-related factors. One potential child-related factor is the children's gestational status (being born preterm or full-term), which broadly relates negatively to children's language (Foster-Cohen et al., 2007) and cognitive (Maxwell et al., 2017) development. Children's mathematical skills are particularly affected by preterm birth (Simms et al., 2013). In terms of environmental factors, mathematical skills are also influenced by the early home numeracy environment, specifically input from the parents (e.g., Anderson

CONTACT Dilay Z. Karadöller dilayk@metu.edu.tr Department of Psychology, Middle East Technical University, Dumlupınar Bulvarı, No:1, Çankaya, Ankara, Turkey

et al., 2004). However, little is known about how such child- and parent-related factors interact during numerical development in preschool years. It is possible for parents to shape their input based on their child's characteristics, such as their language skills. In the domain of language development, for example, previous research showed a relationship between parental verbal and gestural input and preschoolers' vocabulary development as a function of gestational status (Demir-Lira & Göksun, 2024; Göksun et al., 2025). However, no study so far examined how parental numerical input might vary as a function of children's language skills and compared parental numerical input between children born full-term or preterm. Furthermore, the prior literature on numerical input focused only on parental speech. However, numerical input can be provided in speech or via speech-gesture combinations. Here, we examine the interactive relationship between children's gestational birth status (preterm vs. full-term) and their expressive vocabulary on the modality of parental numerical input (speech and speech-gesture combinations). More specifically, we ask how and in what ways children's gestational status and expressive vocabulary uniquely or in interaction are associated with speech-only and multimodal math input.

Early numerical development

Number understanding is an early developing skill, especially for small numbers. Even preverbal babies can process small clusters of objects in terms of numerical magnitude (Starkey & Cooper, 1980; Wynn, 1998). Children's numerical knowledge rapidly increases as they start learning about symbolic numbers (Anuola et al., 2004; Barth et al., 2009). At around the ages of 2–3, children start using abstract numbers for counting and may count objects (e.g., Sarnecka & Lee, 2009). After age 4, children start counting even larger groups of objects. Although all children go through similar steps in their number development, their performance has extensive variability. For example, some children already understand the meaning of number words up to "four" by age 4, whereas others at the same age have not mastered the meaning of the word "one" (Ehrlich, 2007; Ehrlich & Levine, 2007; Klibanoff et al., 2006). This variability is important because numerical knowledge children have by kindergarten entry predicts future mathematics achievement (Duncan et al., 2007). Several factors may be linked to the variability in children's numerical development. Children's biological risk factors, such as prematurity (Simms et al., 2013), their own vocabulary development (LeFevre et al., 2010), and parental language input (Leech et al., 2022; Levine et al., 2010) are all reportedly related to numerical development. However, less is known about the possible interactions between these factors. Thus, a possibility yet to be uncovered is how parental input is shaped based on the child, as parents may tailor their input as a function of the child's vocabulary development and across neonatal status (being full-term and preterm) (see Göksun et al., 2025 for a review).

Parental numerical input

In early parent–child interactions, parents provide different types of input that may scaffold the development of several domains. The role of parental input in children's development is also important during preschool years when parents and children frequently engage in several play and reading activities (e.g., Ünlütabak et al., 2022). Previous work showed positive impact of number-related experiences that occur in home literacy environment

(Leech et al., 2022; Skwarchuk et al., 2014; Susperreguy & Davis-Kean, 2016) as well as parental number talk directed to children during dyadic interactions on children's numerical development (e.g., Anderson et al., 2004; Casey et al., 2018; Elliott et al., 2017; Gunderson & Levine, 2011; Levine et al., 2010; Mutaf Yıldız et al., 2018; Ramani et al., 2015; Susperreguy & Davis-Kean, 2016; Thippana et al., 2020; Vandermaas-Peeler et al., 2012).

One context that is particularly conducive to math talk is book reading. Parents provide math input in shared book-reading contexts (e.g., Anderson et al., 2004; Goldstein et al., 2016; Mix et al., 2012; Salsa et al., 2022). In these contexts, math input is observed in parents' talk very early, starting as early as 5 to 10 months of age (Goldstein et al., 2016). The frequency and complexity of math talk increase as a function of children's age. For example, Goldstein et al. (2016) showed that older infants (i.e., 8- to 10-month-olds) receive more parental input related to mathematical concepts than younger infants do (i.e., 5- to 7-month-olds).

Parents talk about different aspects of numbers in their interactions with their children. Among various numerical concepts, the most frequently used type of math input is counting the number of objects that are present in the environment (Goldstein et al., 2016). Compared to counting, parents make fewer references to cardinality (i.e., the set size of the objects) at younger ages, but the makeup of the numerical talk changes as children get older (Mix et al., 2012). For example, in a study investigating how parents read a book about numbers to their 3.5-year-old children, Mix and colleagues (2012) demonstrated that the most frequent form of math input was cardinality. They reported that counting, on the other hand, was less frequent when compared to cardinality for that age group. Although it is not exactly known when parents shift from counting to cardinality, this shift may happen around age 2, when children themselves start using abstract symbolic numbers to represent the set size of objects (Geary et al, 2007). In addition, other types of math input could be present in parental number talk, such as comparing the number of entities, using units to denote the cardinal number of entities, or the combination of different types. Given the significant shift from counting to cardinality that occurs around age 2 in typically developing children and considering the variability of parental input during this period, we focus on this age range in the current study to examine how parents of preterm children with different developmental trajectories structure their input compared to parents of full-term children.

Parental input could also differ in modality. Information about numbers is not only conveyed in speech alone. Speech input provides arbitrary links between the verbal message and what it refers to in real life. For instance, the sound of "two" does not contain anything about "twoness." There are, in fact, multimodal ways to provide iconic references to ongoing speech, such as by using representational gestures (i.e., gestures that communicate specific meaning such as by using two extended fingers representing number two; e.g., ✌) along with speech. Parents provide auditory input together with visual cues (Gogate et al., 2000) and use co-speech gestures to support their message (Rowe & Goldin-Meadow, 2009). Previous research has highlighted the significance of multimodal input in the development of various domains (e.g., Kısa et al., 2019), and a more comprehensive review of the use of multimodal input can be found in Göksun et al. (2025). Concerning mathematical input, school-aged children reportedly benefit from gestures used by teachers or parents when learning mathematics (e.g., Cook et al., 2013; Cook & Goldin-Meadow, 2006). In addition, several studies showed a positive relationship between multimodal parental input and other aspects of children's broader cognitive development, such as vocabulary (e.g., Choi & Rowe, 2021; Iverson et al., 1999; Pan et al., 2005). Less is known whether and how multimodal input is present when parents communicate numerical information to younger children in general, and to children born preterm more specifically. Similarly, whether and how numerical multimodal input varies as a function of factors related to children's development remains opaque.

Factors relate to parental input

Existing literature primarily focuses on how parental input predicts children's development in various domains (Göksun et al., 2025). However, why parents vary in the input they provide has received less attention. Broader literature on parenting suggests three main sources of influence on parenting behaviors: child characteristics, parent characteristics, and contextual factors (Belsky, 1984). While prior studies have focused on the characteristics of language input that are related to child language, a few earlier research examined the predictors of parental language input (Iverson et al., 2023; Kısa et al., 2019; Kızıldere et al., 2022; Pınar et al., 2021). These studies show how parents tailor their input based on their children's developmental characteristics. Here, we examine the role of two child-related characteristics: preterm birth and vocabulary skills in predicting parental input.

Role of preterm birth

One of the child characteristics that may potentially affect parent-child communication is preterm birth. Infants are considered preterm when they are born earlier than 37 weeks of gestation. One out of 10 births across the world are preterm and the rates are increasing – especially in Western countries (Chawanpaiboon et al., 2019). Infants born preterm usually undergo a certain period of intensive care and may have atypical brain development and physical and psychological impairments (Arpino et al., 2010; Caskey et al., 2011, 2014). They also present delays in cognitive (Maxwell et al., 2017) and linguistic (Foster-Cohen et al., 2007) milestones (see van Noort van der Spek et al., 2012; see also Demir-Lira & Göksun, 2024; Göksun et al., 2025). Environmental conditions, such as placement in NICU or prolonged medical treatments after birth, as well as preterm infants' unresponsiveness to communication, may disrupt early social interactions (Salerni et al., 2007). These early disruptions might have cascading effects on parent–child interactions and have potential implications for multiple domains, which may in turn relate to how parents communicate with their children (Caskey et al., 2011, 2014). No study so far investigated parental math input across full-term and preterm children. A few studies investigated the amount of overall parental verbal input between preterm and full-term children (Adams et al., 2018; Doğan et al., 2021; Özdemir et al., 2024; Salerni et al., 2007). These studies report no difference between the amount of verbal input provided to preterm and full-term children (but see Özdemir et al., 2024). Nevertheless, it is an open area for scientific inquiry as atypically developing children reportedly benefit from high-quality environmental experiences, such as the presence of parental gesture input, to a greater degree compared to their typically developing peers (DeMaster et al., 2019; Gueron-Sela et al., 2015; see also Demir-Lira & Göksun, 2024; Göksun et al., 2025).

Role of vocabulary development

Parents are not just one-sided input providers. What parents do might vary as a function of the child's current developmental status. Children's developmental progress in specific domains, such as vocabulary development, potentially sets the tone, the extent, and the nature of parental input. Several studies demonstrated a close relationship between a child's vocabulary development and parental verbal and gestural input, which we review in the remaining section.

Several studies showed a strong relationship between quality and quantity of parental verbal (see Anderson et al., 2021 for a review), as well as gestural input (e.g., Choi & Rowe, 2021; Iverson et al., 1999; Pan et al., 2005) and typically developing children's vocabulary development. For instance, Pan et al. (2005) found that children's vocabulary grows faster as a function of parental gesture frequency. In a similar vein, studies report that the quantity of parental gestures at 16 and 14 months predicts both concurrent (Iverson et al., 1999) and later vocabulary size (Choi & Rowe, 2021), respectively.

For preterm children, language development seems to be one of the areas where they lag behind their full-term peers (Barre et al., 2011; Foster-Cohen et al., 2007; Putnick et al., 2017; Sansavini et al., 2014 but see Pérez-Pereira & Cruz, 2018). Some studies demonstrated evidence for lower expressive language scores for preterm children compared to full-term children (Foster-Cohen et al., 2007). The difference in vocabulary size between preterm and full-term children may also increase over time (Sansavini et al., 2011). Yet, other studies showed differences in vocabulary size only between very preterm children and full-term children where moderate to late preterm children succeed in between the two groups (Sansavini et al., 2014; see also Demir-Lira & Göksun, 2024).

Overall, parents provide math input during dyadic interactions for typically developing children from very early ages (e.g., Goldstein et al., 2016). Previous work showed a positive relationship between verbal and gestural number input on children's numerical development (e.g., Gunderson & Levine, 2011; Cook & Goldin-Meadow, 2006). There could be several factors that relate to parental input frequency and modality. Here, we investigate the parental number input modality in relation to gestational status (preterm or full-term birth) and children's concurrent vocabulary development.

The present study

Building on the previous work, we investigate the relationship between parental math input modality and type, children's gestational status and vocabulary development. We used book reading as a medium for parental math input in dyadic interaction (see Goldstein et al., 2016, Mix et al., 2012; Ramani et al., 2015; Rowe & Pan, 2004; Salsa et al., 2021 for a similar approach). In book reading situations, parental input is not just restricted to speech but could also be multimodal or allow for several encouraging interactions between the child and the parent (e.g., Ünlütabak et al., 2022) in the domain of math (e.g., Rowe & Pan, 2004).

We asked how and in what ways parents provide math input in speech-only and in speech-gesture combinations and how these differences are related to children's vocabulary development. In each question, we pinpoint if the relations vary as a function of gestational status. With respect to our first question regarding parental input modality (speech-only, speech-gesture combinations), we expect full-term children to receive more input overall (both in speech-only and in speech-gesture combinations) compared to preterm children due to factors impairing the dyadic interaction patterns between preterm children and their parents (e.g., Salerni et al., 2007). Alternatively, preterm children may receive more multi-modal input than their full-term peers based on findings indicating that atypically developing children benefit more from high-quality environmental experiences, such as the presence of parental gesture input (DeMaster et al., 2018; Gueron-Sela et al., 2015; see also Demir-Lira & Göksun, 2024).

With respect to our second question, we expect higher vocabulary scores to be associated with parental math input overall (both for speech-only and for speech-gesture combinations) based on the literature demonstrating evidence for a strong relationship between overall parental input and children's vocabulary (e.g., Anderson et al., 2021; Choi & Rowe, 2021; Iverson et al., 1999; Pan et al., 2005). It is also possible that gestational status and children's vocabulary would interact in predicting parental input. That is, we could expect higher vocabulary scores to predict more math input overall (both for speech-only and or for speech-gesture combinations) differentially for full-term and preterm children based on the possibilities entertained above concerning gestational status.

Method

This study was part of a longitudinal study that examines Turkish-learning children's cognitive and language development. This paper draws data from the third wave of data collection when children were between 24 and 28 months old. The methods reported in this study have been approved by the Ethics Review Board of Koç University, İstanbul, Turkey (Project name: A longitudinal study examining preterm and full-term children's early language and cognitive development-Protocol no: 2018.118. IRB3.083). Informed consent was obtained from the parents.

Participants

Fifty-eight parent–child (preterm: $n = 24$, 10 female, *Corrected Mean Age* = 25.9 months, *SD Age* = 1.32 months; full-term: $n = 34$, 19 female, *Mean Age* = 26.3 months; *SD Age* = 1.37 months) dyads have participated in this study.[1] Fifty-five of the parents were mothers, and three of the parents were fathers. Table 1 presents more details for the preterm group, including gestational week at birth, birth weight, adjusted age at testing (in months), and gender. Data from an additional 7 dyads were excluded as children did not engage with the task during the session.

The sample is relatively homogeneous in parental education and family income, representing families from middle to high socioeconomic status with overall higher education levels. Among 58 families, 7 families had an income below 5000₺, 24 families had an income between 5000₺ and 10,000₺, and 17 families had an income above 10,000₺ at the time of

[1]The number of participants was restricted due to COVID-19 related research regulations at the time of testing.

Table 1. Distribution of preterm children by gestational week at birth, birth weight, adjusted age at testing (in months), and gender.

Participant Number	Gestational Week at Birth	Birth Weight	Adjusted Age at Testing (in months)	Gender
101	28	1140	28.12	female
102	23	890	27.17	male
103	28	1100	25.82	female
105	25	825	30	male
108	34	2240	25.2	female
109	32	1845	24.71	male
114	27	1125	27.43	female
120	35	1770	25.79	female
121	35	2370	25.79	female
122	27	1070	25.99	female
123	27	825	25.99	female
124	28	1300	24.74	male
125	29	1100	26.38	female
141	29	1000	25.07	male
147	32	1800	26.18	male
148	27	1300	25.63	female
149	33	2100	24.67	male
150	33	1890	24.67	male
161	33	2560	26.64	male
162	29	900	25.66	female
164	29	1560	25.23	male
167	29	1380	25.26	female
173	27	800	24.08	female
209	34	2015	24.34	male

testing. We do not have income data for 10 families. Moreover, 82.8% of the mothers (n = 48) and 75.9% of the fathers (n = 44) had a university degree or higher.

Materials

The very hungry caterpillar book

A wordless version of The Very Hungry Caterpillar book, written by Eric Carle, was used. Parents were not provided with specific instructions and were free to engage with the book as they wished. The book contained picture pages that could elicit math input where the caterpillar is illustrated as eating one apple, two pears, three plums, four strawberries, and five oranges. Although the book used in our study was wordless, nine of the 34 parents from the full-term group happened to know the story. We determined their knowledge of the original script based on whether or not they referred to the days of the week (e.g., "*On Monday the caterpillar ate one apple.*") or the caterpillar eating different fruits on consecutive days without mentioning the weekdays (e.g., "*The caterpillar ate one apple on the first day. On the second day, he ate two pears.*"). To control whether the knowledge of the script affects parental math input we performed Kruskal-Wallis tests (the non-parametric version of One-way ANOVAs due to the difference between sample sizes) for word count, utterance count, speech-only and multimodal math input across children whose parents do and do not know the script. Analyses revealed that differences were not significant (all ps < .05). Therefore, we included data from all parents in the further analyses, regardless of their knowledge of the script. The average session duration for all groups was 4 minutes 53 seconds (*preterm*: 4 minutes 52 seconds;

full-term: 4 minutes 54 seconds) with a standard deviation of 1 minute 5 seconds (*preterm*: 1 minute 18 seconds; *full-term*: 56 seconds). There were no differences in the session duration between the two groups ($t(56) = 0.154$, $p = 0.88$).

Turkish communicative development inventory (TCDI-II; Aksu-Koç et al., 2019)

Parental reports of children's expressive vocabulary knowledge were measured through the Turkish adaptation of MacArthur Bates CDI (Fenson et al., 2000) named Turkish Communicative Development Inventory (TCDI-II; Aksu-Koç et al., 2019). TCDI-II has 711 items and was normed on children aged 8–36 months. TIGE-II has .99 Cronbach's alpha for internal consistency (Aksu-Koç et al., 2019). We obtained a total vocabulary score per child.

Procedure

Testing was done either at the Koç University - Langauge and Cognition Laboratory or in a silent room at Metin Sabancı Healthcare Center in downtown İstanbul, where we created a lab-like environment. Upon arrival at the experimental setting, infants were initially warmed up with the room and the experimenter. Infant-parent dyads engaged in the 5-minute book reading session. Some parents finished reading the book earlier than 5 minutes. During this session, parents were asked to read the book as they usually would read at home. Parents were not primed to engage in a certain way of reading to ensure spontaneity and ecological validity. After the instruction, the experimenter left the room, and the parent–child dyads engaged in the book-reading activity in the experimental room. The session was videotaped for later transcription and coding. Parents then completed the Turkish adaptation of MacArthur Bates CDI via e-mail. Note that dyads engaged with various other activities in this wave of data collection as part of a bigger project. The entire session took approximately 75-min. The whole session included a fixed order of tasks measuring gesture comprehension (i.e., gesture comprehension task), executive functioning (i.e., hide the pots and categorization tasks, see Bernier et al., 2010), receptive language (i.e., TİFALDİ task, see Kazak-Berument & Güven, 2013) and parental math input (i.e., book-reading session). Thus, the book reading session was conducted as the 5th task. At the end of the experiment, infants received a book as a gift, and their parents received 50₺ compensation payment for their transportation expenses.

Coding

The entire book-reading session was transcribed and coded using ELAN (Version 4.9.3), a free annotation tool (http://tla.mpi.nl/tools/tla-tools/elan/) for multimedia resources developed by the Max Planck Institute for Psycholinguistics, The Language Archive, Nijmegen, The Netherlands (Wittenburg et al., 2006). Following CHILDES protocols (MacWhinney, 2007), all parental and child utterances were transcribed by native speakers of Turkish. An utterance was defined as one grammatical sentence or a shorter phrase prosodically marked as a separate utterance (see also Hurtado et al., 2008).

Parental math input coding in speech and in gesture was done on the utterance level. All coding was performed twice by two native Turkish speakers, and all disagreements were resolved via discussion. Later, 20% of the randomly selected data was coded by another native speaker of Turkish for reliability checks. There was an almost perfect agreement for speech (Agreement: 97.62%; Kappa: 0.87) and also for gestures (Agreement: 99.55%; Kappa: 0.95). We did not code for child input, as this is an age in which children do not talk much and rarely produce number talk. That is, 44 out of 58 children did not use any number words and those who used number words did so only exclusively after being prompted to "count" or "repeat after."

Speech

We coded for the presence of specific types of Math input that consisted of 4 categories: cardinality, counting, comparison, and unit of measurement. Cardinality refers to the cases when parents used numbers to refer to the total number of objects. Counting refers to the cases when parents perform counting (not necessarily starting from number 1). Comparison refers to cases where parents emphasize comparing the number of entities in terms of consecutiveness, smallness, or greaterness. The unit of measurement[2] refers to cases when a number is renounced by a measurable unit (see Table 2 for examples). In some cases ($n = 42$), the descriptions fell into a combination of counting and cardinality, we counted them as Combination.

Gesture

We further coded spontaneous co-speech gestures as identified by strokes (see Kita et al., 1998) produced by parents that conveyed information regarding the number of objects either by showing the number with extended fingers (e.g., two open and extended fingers to represent two pears), pointing to the objects with open and extended fingers (e.g., two open and extended fingers were each finger is pointing to one of the pears), pointing to each fruit while counting, and showing the entire set of objects referred to in the speech. We did not consider other types of gestures, such as beat gestures and gestures representing object properties such as size and shape since the main focus of the current paper was on numerical input. We computed this coding per utterance.

Table 2. Examples of math input types in Turkish (TR) and English (EN) translation.

Category	Example
Cardinality	TR: Tırtıl *beş* portakal yemiş EN: Caterpillar ate *five* oranges
Counting	TR: *bir, iki, üç* EN: *one, two, three*
Comparison	TR: Bir armut yedikten sonra, *ikinci* armudu da yemiş EN: After eating one pear, he ate *the second* pear
Unit of Measurement	TR: Tırtıl *üç kilo* portakal yemiş EN: The caterpillar ate *three kilos* of oranges
Combination	TR: Tırtıl *bir, iki, üç* erik yemiş. EN: Caterpillar ate *one, two, three* plums.

[2]In Turkish, the cardinal number of objects is referred by using the word "*tane*" (~piece). The word *tane* denotes countable objects as a unit and is frequently used in Turkish, although sentences mentioning the cardinal number of objects are grammatically correct without using it. In our initial coding attempt, 93.55% of the unit of measurement utterances included *tane*. We considered these cases within the cardinality type and included only the cases where objects are referred with other measurable units (e.g., kilos).

Table 3. Frequency distribution for types of input across preterm and full-term children.

	Speech-Only	Multimodal
Preterm		
Cardinality	56	40
Counting	9	7
Comparison	0	7
Unit of Measurement	0	0
Combination	1	11
Total	66	65
Full-term		
Cardinality	65	172
Counting	4	37
Comparison	12	17
Unit of Measurement	8	10
Combination	2	28
Total	91	264

Next, we combined speech and gesture coding and created two categories: (1) Speech-only descriptions that consist only of speech utterances without accompanying gestures, and (2) Multimodal descriptions that consist of utterances that include speech-gesture combinations. There were only a few cases ($n = 6$) where parents executed math gestures in the absence of math talk. We did not count them as multimodal math input and disregarded them in the analyses. We also created sub-types for speech-only and multimodal input based on our input type coding. Please see Table 3 for the number of cases falling into each category. Finally, we calculated the proportions of speech-only or multimodal input by dividing them by the total number of utterances.

We investigated how and in what ways children's gestational status and expressive vocabulary scores contributed to speech-only and multimodal math input by running two hierarchical regression models. We further performed post hoc sensitivity analysis for our models using the G*Power software package (Faul et al., 2007). We calculated the effect size by taking the sample size as 58, the alpha level as .05, and the power as .95. The sensitivity analysis revealed an effect size of .282 for models with a total of four predictors, indicating our models have the capacity to detect meaningful, moderate size relationships among predictors. The calculated effect size based on this sensitivity analysis aligns well with the R^2 we found for the models testing multimodal input (see Table 5). Considering limited resources in data collection (observational longitudinal data collection from atypically developing young children and their parents from a country that is typically underrepresented in developmental science), this sample was sufficient to detect effects typically reported in the literature.

Results

Preliminary analyses

The mean number of words in parental speech was 464 ($SD = 106$, $Range = 185–760$), and the mean number of utterances parents used was 131 ($SD = 25.9$, $Range = 66–184$). There was a high correlation between the number of words and utterances ($r = 0.83$, $p < 0.001$). There was no significant difference in terms of the number of utterances that full-term ($M = 128$, $SD = 22.7$) and preterm ($M = 128$, $SD = 30.4$) children received during the book

Table 4. Intercorrelations between speech-only input, multimodal input, gestational status, expressive vocabulary scores, and utterance count.

	Speech Only Input	Multimodal Input	Gestational Status	Expressive Vocabulary	Age at Testing	Utterance Count
Speech Only Input	—					
Multimodal Input	0.258	—				
Gestational Status	0.071	0.453***	—			
Expressive Vocabulary	−0.091	−0.209	0.085	—		
Age at Testing	0.220	0.204	0.173	0.173	—	
Utterance Count	0.153	−0.013	−0.012	0.326*	−0.184	—

Note. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

reading session, $t(56) = 0.09$, $p = 0.931$. Similarly, there were no differences in the number of words full-term ($M = 455$, $SD = 115$) and preterm ($M = 470$, $SD = 102$) children received during the book reading session, $t(56) = -0.53$, $p = 0.598$ (see Table 4 for the correlations between tested variables).

Next, we tested the frequency of different types of math input across groups and modalities. Cardinality emerged to be the most frequent input type and other types were either not used at all or used at very low frequencies, making it difficult to examine the individual role of each subcategory. Thus, we compared cardinality to all the remaining types (counting, comparison, unit of measurement, combination) grouped together as *other*. Results of repeated measures ANOVAs showed cardinality as the most frequent form for both speech-only and multimodal input (*speech-only:* $F(1, 56) = 28.646$, $p < 0.001$; *multimodal:* $F(1, 56) = 11.820$, $p = 0.001$) regardless of the gestational status of the child (*speech-only:* $F(1, 56) = 0.564$, $p = 0.456$; *multimodal:* $F(1, 56) = 1.370$, $p = 0.246$). See Table 3.

Main analyses

We carried out two hierarchical regression models with the outcome variables as *Speech-only math input* and *Multimodal math input*, respectively. For both models, the first step included age at testing[3] as a control variable, the second step included children's expressive vocabulary score and gestational status as predictor variables, and the third step included an interaction term between children's expressive vocabulary score and gestational status as predictor variables.

For speech-only input, the regression model was not significant at the first ($F\ (1, 54) = 3.36$, $p = 0.072$), second ($F\ (3, 52) = 1.45$, $p = 0.239$) or third ($F\ (4, 51) = 1.12$, $p = 0.359$) steps (see Tables 5–6 and Figures 1–2 for more details).

For multimodal input, the model was not significant at the first step, $F\ (1, 54) = 2.69$, $p = 0.107$. However, the second step improved the model significantly ($\Delta R^2 = 0.24$, $F\ (2, 52) = 8.55$, $p < 0.001$) and explained 28% of the total variance, $F\ (3, 52) = 6.85$, $p < 0.001$. Children's expressive vocabulary score was a significant predictor ($\beta = -0.277$, $p < 0.024$). In particular, the higher the children's expressive vocabulary, the lesser multimodal input they received. Moreover, gestational status was another significant predictor ($\beta = 0.860$, $p <$

[3]Controlling for some other variables such as child's gender and parental education did not improve the models significantly. For brevity, here, we only report the model with age at testing as a control variable.

Table 5. Differential contributions of child's expressive vocabulary scores and gestational status separately for speech-only and multimodal input.

Outcome: Speech Only Math Input						Outcome: Multimodal Math Input					
Predictors	*B*	*SE(B)*	*β*	*p*	*R2*	Predictors	*B*	*SE(B)*	*β*	*p*	*R2*
Step 1				0.072	0.059	Step 1				0.107	0.048
Age at Testing	0.004	0.002	0.242	0.072		Age at Testing	0.008	0.005	0.218	0.107	
Step 2				0.239	0.077	Step 2				<.001	0.283
Age at Testing	0.004	0.002	0.263	0.061		Age at Testing	0.007	0.004	0.187	0.128	
Gestational Status	<.001	0.006	0.032	0.907		Gestational Status	0.041	0.011	0.860	<.001	
Expressive Vocabulary	-<.001	<.001	−0.138	0.314		Expressive Vocabulary	<.001	<.001	−0.349	0.009	
Step 3				0.359	0.081	Step 3				<.001	0.343
Age at Testing	0.004	0.002	0.270	0.058		Age at Testing	0.006	0.004	0.160	0.180	
Gestational Status	−0.004	0.011	0.032	0.756		Gestational Status	0.080	0.021	0.862	<.001	
Expressive Vocabulary	-<.001	<.001	−0.196	0.310		Expressive Vocabulary	-<.001	<.001	−0.032	0.843	
GestStatus*ExpresVocab	<.001	<.001	0.118	0.665		GestStatus*ExpresVocab	-<.001	<.001	−0.494	0.036	

Table 6. Descriptives for multimodal math input, speech-only math input, and expressive vocabulary scores.

	Mean	SD	Minimum	Maximum
Multimodal Input				
Total	0.043	0.046	0	0.19
Preterm	0.020	0.023	0	0.09
Full-term	0.059	0.051	0	0.19
Speech-Only Input				
Total	0.022	0.021	0	0.09
Preterm	0.019	0.020	0	0.08
Full-term	0.024	0.022	0	0.09
Expressive Vocabulary				
Total	423	250	6	711
Preterm	397	289	16	709
Full-term	440	224	6	711

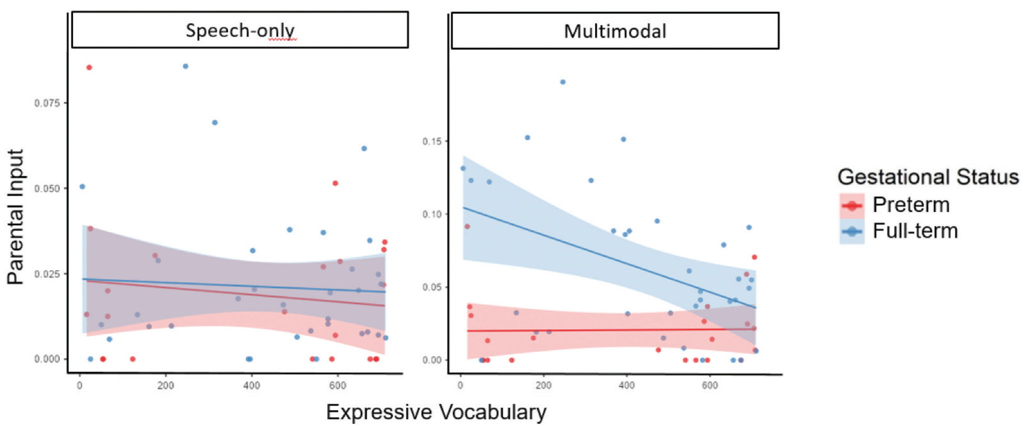

Figure 1. Relationship between gestational status and expressive vocabulary scores for Speech-only and multimodal math input. Colored dots represent the average data of each participant. Shaded areas around the lines represent the standard error of the mean.

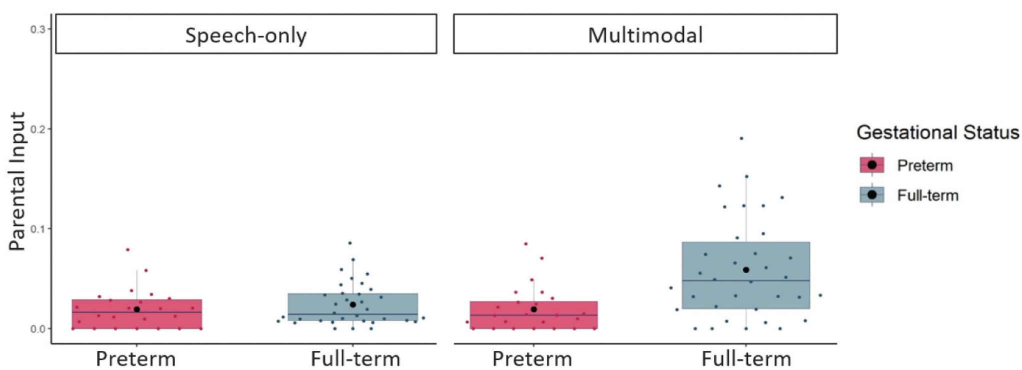

Figure 2. Proportions of speech-only and multimodal math input across preterm and full-term children. Colored dots represent the average data of each participant. Black dots represent the mean.

0.001). Full-term children ($M = 0.06$; $SD = 0.05$) received more multimodal input than preterm children ($M = 0.02$; $SD = 0.02$). Adding an interaction term between children's expressive vocabulary score and gestational status at the third step improved the model significantly ($\Delta R^2 = .06$, $F\,(1, 51) = 4.65$, $p = 0.036$) explaining 34% of the total variance, $F\,(4, 51) = 6.66$, $p < 0.001$. Lower expressive vocabulary scores were associated with higher multimodal math input for full-term children. However, there was no association between expressive vocabulary and multimodal math input for preterm children (see Tables 5–6 and Figures 1–2 for further details).

Discussion

This study investigated the relationship between parental math input, children's gestational status, and vocabulary development. We asked how math input parents provided in speech-only and speech-gesture combinations were associated with the interactive relations between children's gestational status and vocabulary development. Using book reading to capture dyadic interaction between parents and 26-month-old children in Türkiye, we coded parental math input in speech and speech-gesture combinations that full-term and preterm children received. We also obtained parental reports for their child's expressive vocabulary proficiency by filling out Turkish CDI (Aksu-Koç et al., 2019). Our results demonstrated that multimodal, but not speech-only, math input was related uniquely to gestational status and expressive vocabulary as well as to their interaction. Full-term children with lower expressive vocabulary scores received more multimodal input compared to preterm children. Nevertheless, there was no association between expressive vocabulary and multimodal math input for preterm children. Furthermore, cardinality stood out as the most frequently occurring input type among others (counting, comparison, unit of measurement, and combination) for both speech-only and multimodal input.

In general, our findings concerning parental input modality and gestational status align well with earlier work showing that parental speech-only input does not relate to differences across full-term and preterm children (Adams et al., 2018; Salerni et al., 2007, but see; Özdemir et al., 2024) but only multimodal input does (Göksun et al., 2025; see also Demir-Lira & Göksun, 2024). Parents of full-term and preterm children provided similar frequencies of speech-only input during book reading sessions despite stressful factors that could influence dyadic interactions (Bilgin & Wolke, 2015; Korja et al., 2010). Likewise, the presence of fewer multimodal input for preterm children than full-term children was consistent with our expectation regarding several factors potentially impairing the dyadic interaction patterns between preterm children and their parents (Salerni et al., 2007). Nevertheless, this pattern may contradict previous reports suggesting that atypically developing children benefit more from high-quality environmental experiences, such as the presence of parental gesture input (DeMaster et al., 2018; Gueron-Sela et al., 2015; see also Demir-Lira & Göksun, 2024). Based on these reports, one would expect parents of preterm children to provide richer input via speech-gesture combinations. Within several possibilities, one explanation for these patterns might stem from parental theories of intelligence (Dweck, 2000). Previous reports showed a strong relationship between parental involvement and parents' belief in the changeability of intelligence (Jiang et al., 2019). Following this relationship, parents of preterm children might potentially believe that their children are not ready or receptive to richer environmental experiences, and multimodal math input in this specific context. Nevertheless, our study was not set to disentangle this possibility, and we suggest further research to investigate the role of parental epistemologies in the relationship between parental input in atypically developing children. Moreover, this finding also aligns well with previous reports showing how parents can tailor their input based on their children's developmental progress in several domains (e.g., Iverson et al., 2023; Kısa et al., 2019; Kızıldere et al., 2022; Pınar et al., 2021).

Our findings are relatively inconsistent with the previous literature that has shown a positive relationship between vocabulary development and overall parental input (Anderson et al., 2021; Choi & Rowe, 2021; Iverson et al., 1999; Pan et al., 2005). Here, we found an opposite relationship between parental input and vocabulary, and we found this only for multimodal math input. It is essential to consider this finding together with the gestational status of the child. Interestingly, we found for the first time that although preterm and full-term children received similar levels of speech-only input, parents provided richer math input (speech and gestures combined) only to full-term children with low expressive vocabulary scores. It is possible that parents provide richer input to foster their children's development when children have lower vocabulary. By contrast, parents of preterm children may refrain from using richer input patterns due to their children being not ready or receptive. Finally, our results may also be driven by children's own multimodal production. However, as the task design (i.e., book-reading) does not explicitly require children's input, we could not directly measure this. Yet, the examination of the dyadic relation between parental multimodal input and children's multimodal production could be an excellent avenue for future studies. Overall, our results have the potential to provide insights into the interrelationship between gesture and speech for atypically developing children, which might be different from typically developing children (see Demir-Lira & Göksun, 2024).

In this study, we also coded the differences in the frequency of types of math input used in speech-only and multimodal utterances. Cardinality stood out as the most frequently used type in both speech-only and multimodal input regardless of the gestational status. These findings are important in corroborating existing literature on cardinality, which is the most common form of number talk around 14 to 30 months (Gunderson & Levine, 2011) and beyond (Mix et al., 2012). Besides, our results extend the existing literature by introducing a language-specific math input pattern. That is, almost 78% of cardinality utterances contain "*tane*" which denotes countable objects as a unit, and it is frequently used in Turkish. Although sentences with or without *tane* are grammatically correct and express the same meaning (e.g., sentences "*Beş portakal varmış*" and "*Beş tane portakal varmış*" both mean "*There were five oranges*" irrespective of the use of the word *tane* or not).

Limitations and future directions

The current study has a broad gestational age spectrum within the preterm group. A fruitful avenue for future investigation is to compare and contrast very-preterm children to moderate-to-late preterm and full-term children, as previous work demonstrated higher risks for the very-preterm children with respect to cognitive and linguistic development (e.g., Suttora & Salerni, 2012; Putnick et al., 2017; Sansavini et al., 2011) and more pronounced differences across very preterm and full-term children (see Demir-Lira & Göksun, 2024 for a review). We could not implement this comparison here due to the low number of participants falling into the very preterm category. Moreover, although this study nicely demonstrated differences in parental input modality and type across full-term and preterm children through a cross-sectional design by also considering their vocabulary development, future studies should also consider whether and how differences in parental math input relate to differences in numerical development both concurrently and longitudinally. Although the overall sample came from a country/language background that is underrepresented in developmental science, the sample consisted of families from middle to high socioeconomic status with overall higher education levels. In this respect, the sample might have low generalizability across several SES strata, which have been reported to affect the quantity and the quality of parental input directed to children (e.g., Rowe, 2008, 2012). Finally, this study only investigates biologically related parents and their children, it is possible that shared genes between parents and children may explain some variance in the amount of math input parents provide to their children. We suggest future research to investigate potential correlates stemming from shared genetic variance by also testing parents and their adopted children.

Conclusion

In conclusion, these results add to the existing literature showing that not only overall multimodal input and the use of parental gestures but also the specific type of multimodal input (i.e., math input) is conveyed as a function of children's gestational status and vocabulary development. Moreover, results demonstrated that cardinality is the most frequently used input type for 26-month-old children, regardless of the gestational status. This study has the potential to provide insights into the interrelationship between gesture and speech for preterm-born children, which might be different from full-term-born children (but see Demir-Lira & Göksun, 2024). Finally, the overall results of this study reveal the importance of considering parental input modality as a factor in investigating several other domains of development.

Disclosure statement

No potential conflict of interest was reported by the author(s).

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ORCID

Dilay Z. Karadöller http://orcid.org/0000-0001-5160-7679
Ö. Ece Demir-Lira http://orcid.org/0000-0002-8506-0250
Tilbe Göksun http://orcid.org/0000-0002-0190-7988

Data availability statement

The data that support the findings of this study are available on request from the corresponding author Dilay Z. Karadöller. The data are not publicly available due to restrictions containing information that could compromise the privacy of research participants, such as the names of the participants.

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