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ARTICLE

Maternal underestimations and overestimations of their infants' word comprehension: effects on mothers' verbal input and infants' receptive vocabulary

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Abstract

Infants' language is often measured indirectly via parent reports, but mothers may underestimate or overestimate their infants' word comprehension. The current study examined estimations of mothers from diverse educational backgrounds regarding their infants' word comprehension and how these estimations are associated with their verbal input and infants' receptive vocabulary at 14 months. We compared 34 infants' looking-while-listening (LWL) performances with the mothers' Turkish Communicative Development Inventory (TCDI) reports to calculate the mothers' overestimation and underestimation. During free-play sessions, we assessed the mothers' number of words, number of clauses, lexical diversity, and linguistic complexity. We found that mothers have overestimations and underestimations regardless of their educational background. Crucially, mothers' only overestimations were positively associated with their number of words and lexical diversity. Mothers' verbal input was not related to infants' receptive vocabulary scores. The findings suggest that mothers' input might be aligned with their estimations of their infants' language capabilities, which might not reflect the infants' true performance.

Keywords: maternal verbal input; receptive vocabulary; socioeconomic status; mothers' estimations of infants' language

Özet

Bebeklerin dil becerileri sıklıkla ebeveynlere sorularak dolaylı olarak ölçülür. Ancak ebeveynler bebeklerinin kelime anlama becerilerini olduğundan daha düşük veya yüksek değerlendirebilir. Bu çalışma, farklı eğitim geçmişlerine sahip annelerin bebekleri 14 aylıkken kelime anlama becerilerine dair tahminlerini ve bu tahminlerin, bebeğe yönelttikleri dil ve bebeklerin dil anlama becerileri ile ilişkilerini incelemiştir. 34 bebeğin kelimeleri anlama becerisi Dinlerken Bakma metoduyla ve annelere sorularak ölçüldü. Bu iki ölçüm karşılaştırılarak annelerin olduğundan

düşük ve yüksek tahmin düzeyleri belirlendi. Serbest oyun oturumlarında, annelerin kullandığı kelime ve cümlecik sayısı, kelime çeşitliliği ve dilbilimsel seviye değerlendirildi. Sonuçlar annelerin, eğitim düzeylerinden bağımsız, bebeklerinin kelimeleri anlama becerilerini doğru tahminlerine ek olarak olduğundan yüksek ve düşük de tahmin ettiklerini göstermiştir. Annelerin düşük tahminlerinin değil, yalnızca yüksek tahminlerinin, bebeğe yönelttikleri konuşmadaki kelime sayısı ve çeşitliliği ile pozitif ilişkiliyken, bebeklerin dil anlama puanları ile ilişkili bulunmamıştır. Bulgular, annelerin dil girdilerinin, bebeklerinin dil becerilerine yönelik tahminleriyle uyumlu olabileceğini, ancak bu tahminlerin bebeklerin gerçek performansını yansıtmayabileceğini göstermektedir.

Anahtar sözcükler: sözel girdi; kelimeleri anlama becerisi; sosyoekonomik statü; annelerin bebeklerin dil becerisine ilişkin tahminleri

The relationship between parental input and infants' language development is commonly studied. Both the quantity and the quality of the caregivers' verbal input are predictors of the infants' emerging language skills (e.g., Anderson et al., 2021; Cartmill et al., 2013; Rowe, 2008). Studies also demonstrated that a higher socioeconomic background is associated with enhanced verbal input and child language outcomes (e.g., Huttenlocher et al., 2007; Hoff-Ginsberg, 1990). However, the studies investigating the association between caregivers' verbal input and early language ability markers such as vocabulary often used indirect measurement tools such as parental reports (e.g., MacArthur-Bates Communicative Development Inventory [MB-CDI]; Fenson et al., 2006; Hsu et al., 2017; Rowe, 2000) rather than direct measurements. Only a few studies have examined the extent to which these indirect measures reflect the infants' actual language skills and demonstrated that parents might estimate their infants' vocabulary skills to be different from their actual competence, especially for comprehension (e.g., Houston-Price et al., 2007; Bennetts et al., 2016). Parents' estimations of their infants' vocabulary skills refer to the extent of congruency between the infants' actual vocabulary knowledge and parents' evaluations of their infants' vocabulary knowledge. For example, parents may think that their infants comprehend a word even though they do not yet comprehend it, or parents may think that their infants do not yet comprehend a word even though they indeed do comprehend it. Assessing word comprehension in infants may be challenging for mothers for several reasons. Infants have limited verbal abilities, often they communicate through nonverbal cues that may not always clearly indicate understanding, and exhibit variable responses to words, making it challenging to gauge their comprehension reliably. Therefore, parents are likely to estimate comprehension of vocabulary differently than their infants' actual performance. As a result of parents' level of estimation of their infants' comprehension, there may be differences in the quantity and quality of the verbal input they provide to their infants. For instance, overestimating parents may give a larger number of utterances with greater morphosyntactic complexity to their infants compared with underestimating parents, because the former attribute more knowledge than the actual level to their infants and tailor their language accordingly. Moreover, such differences in the quality and quantity of input that may be found due to parents' estimations can affect the infants' language development depending on the extent to which input is tailored to the infants' estimated developmental level or needs.

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Parental verbal input and infants' language

Early language skills of children are important correlates of their cognitive, academic, and social skills, such as executive functions (e.g., Wade et al., 2014), academic success (e.g., Agostin & Bain, 1997), and emotion-regulation (e.g., Hentges et al., 2021). Regarding the predictors of children's early language development, most studies have focused on measures of quantity and quality of parental input. While input quantity refers to the number of words, tokens, or utterances spoken to the child, input quality refers to the complexity and variety of the linguistic forms found in child-directed speech. Many studies demonstrated that quantity (e.g., Hart & Risley, 1995; Cartmill et al., 2013) and quality (e.g., Rowe, 2012; Weizman & Snow, 2001) of parental input are associated with children's concurrent and prospective language skills. A recent meta-analysis showed that for child language development, input quality, such as the variety of vocabulary and grammatical complexity of the language spoken to children, is a stronger predictor of child language than input quantity, such as the total number of words and utterances (Anderson et al., 2021).

The findings that show a strong association between parental input and early language skills raise a question about how parental input can promote language development. To answer this question, the concept of Vygotsky's (1978) zone of proximal development (ZPD) and scaffolding may help our understanding. Vygotsky (1978) suggests that the most effective interaction between mothers and children occurs when mothers provide instructions beyond the child's current abilities but within their potential skills, specifically within the child's ZPD. Scaffolding is the support mechanism of ZPD and refers to parents modifying their input in the manner of their infants' skills. Parents modify their verbal input during interaction according to infants' communicative needs and develop language skills (Hart & Risley, 1995). Changes in the quantity and quality of parental input with infants' age can exemplify this modification. For example, Huttenlocher et al. (2007) investigated the changes in caregivers' verbal input when their infants were between 14 and 30 months. Their results demonstrated that while the complexity and diversity of caregivers' input increased over time, the quantity did not change. The authors interpret their findings as such that the changes in caregivers' input result from their sensitivity to children's language level rather than increasing motivation or interest in talking to older children since their input quantity is constant over time. In addition, a few studies indicated the relationship between the earlier language of children and caregivers' later verbal input (e.g., Huttenlocher et al., 2010; Fusaroli et al., 2019; Kızıldere et al., 2022). For instance, Fusaroli et al. (2019) showed that while child word tokens and mean length of utterance (MLU) negatively predicted caregivers' subsequent MLUs, child word types positively predicted caregivers' subsequent MLUs. Overall, these findings suggest that parents might make a prediction about their infants' language proficiency and adjust their input accordingly. Therefore, investigating the association between parents' estimations of their infants' language skills, the verbal input they provide, and the infants' language development is essential to come to a better understanding of parent-driven factors in child language.

Effect of socioeconomic state on parental verbal input and child language

One important factor affecting the association between parental input and child language development is the family socioeconomic status (SES). SES is related to individual differences in parent–child interaction, such as scaffolding and responsiveness (Baydar & Akcinar, 2015; Hoff et al., 2002). It is possible that a relationship between parental behaviour and SES could be explained in terms of parental goals and values that drive

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parental behaviour (Hoff et al., 2002). For instance, parents from high SES are more likely to easily gain knowledge about child development (Rowe et al., 2015). In addition, previous studies showed that high-SES parents tend to believe that their behaviour has an impact on their children's socio-cognitive development (e.g., Bornstein et al., 2003; Bornstein et al., 2019) and they are more sensitive, less controlling, and cognitively more stimulating (e.g., Koşkulu et al., 2021; Tamis-LeMonda et al., 2009) compared with low-SES parents. Family SES is also associated with the functions of parental talk to children. For example, Hart and Risley (1995) found that high-SES parents responded more to their children and produced more affirmations, encouragements, and fewer prohibitions. These findings suggest that diverse SES backgrounds are associated with different parenting behaviours that affect parent–child communicative interaction. Moreover, it may be possible to find traces of the differences in parenting behaviours in parental verbal input across diverse SES. For instance, more educated parents who are more sensitive can perceive their children's needs and interests better, and provide verbal input accordingly. In turn, their input might lead to advantages in their children's language outcomes.

Quantity and quality of parental language input are also closely related to SES (e.g., Huttenlocher et al., 2007; Huttenlocher et al., 2010; Hoff-Ginsberg, 1990). For instance, Houston-Price et al. (2007) investigated parental input from diverse SES backgrounds to their children (aged 14–30 months) in a longitudinal design. They used two measures of SES, namely income and education. Although income and education levels were correlated, education was more strongly associated with parents' input. Furthermore, highly educated parents produced more input with greater syntactic complexity than less educated parents. Input quantity and quality differences among families with different SES also affected children's language skills. Children whose parents are from high SES and who produce more word tokens and input types have better vocabulary skills than those from low SES (Hoff, 2003; Huttenlocher et al., 2010). Last but not least, SES backgrounds might also be related to parents' estimations regarding their children's language skills. In the following section, we present the extent to which there is congruence between parent-reported and directly measured language skills of infants and findings on the effect of SES backgrounds on this congruence.

Congruence between parent-reported and directly measured language skills of infants

The most common tool to measure infants' early language, especially vocabulary skills, is through parental reports such as MB-CDIs (e.g., Rowe, 2000). Nevertheless, studies indicate that evaluating infants' language skills through parental reports yields inconsistent findings compared with more direct measures. In a recent study, López Pérez et al. (2023) investigated the relation between parents' word production reports via CDI and looking while listening (henceforth looking-while-listening [LWL]) performances of their children aged 14–31 months. They found that LWL performance of an individual word was better for children who were reported as producing that word; namely, LWL scores and parent-reported word production skills in MB-CDI scores were significantly correlated. On the other hand, parent-reported word production skills were no longer significantly correlated with LWL scores, when age and total vocabulary size were controlled for. In addition, Houston-Price et al. (2007) examined infants' preferential looks at the target pictures for the 16 words their parents reported as comprehended or not yet comprehended on the CDI. The findings revealed that infants accurately directed

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their attention to the target pictures for both words parents claimed they comprehended and those reported as not yet comprehended. In other words, parents underestimated their infants' word comprehension in their reports. Styles and Plunkett (2009) investigated whether parental reports accurately reflect infants' comprehension of individual words for 12 words. In contrast with Houston-Price et al. (2007), they found that parental reports on CDI were associated with 18-month-old infants' performance in a preferential-looking paradigm. Furthermore, Bennetts et al. (2016) used CDI as a parental report and the Early Communication Indicator (ECI) as a direct measurement that aims to assess children's vocalisations, single words, multiple words, and gestures derived from observations of parent–child interactions. Their findings highlighted a more pronounced consistency between parent-reported and directly measured child language for children exhibiting either poor or strong language skills. The authors suggested that biases related to a parent's background may affect parent-reported measures. For instance, parents from low socioeconomic backgrounds, characterised by low income and low education, have been reported to overestimate their children's vocabulary as assessed by the CDI (Feldman et al., 2000; Reese & Read, 2000). One possible explanation might be related to parents from low SES backgrounds showing lower levels of parental sensitivity and responsiveness in general (e.g., Tamis-LeMonda et al., 2009). Thus, they may make more estimation errors in their infants' word comprehension as they are not as attuned to the subtle cues of infants indicating an understanding of word meaning in everyday life. Regarding overestimations, less educated parents might rate words as relatively easy or difficult in general, and they may assume their child understands a broader range of words, particularly those thought to be easier. Another explanation is that less educated parents might need help distinguishing between "comprehends" and "comprehends and produces" on a vocabulary checklist, leading to an overestimation of their child's vocabulary skills (Reese & Read, 2000). This could be more true during infancy, especially when infants are not yet producing words extensively. Despite the absence of prior empirical support, parents' tendencies to underestimate or overestimate their infants' language abilities may be associated with the verbal input they provide. Indeed, parents might be attuned to the estimated language skills of their infants and adjust their verbal input according to their own estimation.

Current study

The current study extends the literature by investigating parents' (mothers') estimations regarding their infants' word comprehension across diverse educational backgrounds and the relation of these estimations to the verbal input that they provide for their infants. We asked whether (1) mothers overestimate or underestimate their infants' word comprehension (2) mothers' underestimations and overestimations are associated with their years of education, (3) mothers' underestimations and overestimations are associated with the quality and quantity of their verbal input, and (4) the quantity and quality of mothers' verbal input are related with their infants' receptive vocabulary skills. First, based on previous findings we expected mothers might both overestimate and underestimate their infants' word comprehension (Houston-Price et al., 2007; Lopez-Perez et al., 2024), and mothers' years of education would be associated with their estimations (Feldman et al., 2000; Reese & Read, 2000). Specifically, mothers' years of education might be negatively associated with overestimations regarding their infants' word comprehension. On the other hand, the relationship between underestimations and SES

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background is less clear. Second, we expected that mothers' estimations would be related to their verbal input. Mothers who underestimate their infants' word comprehension would provide input lower in quantity and quality to their infants since they might think that their infants could not yet process more complex input. On the contrary, mothers who overestimate their infants' word comprehension would produce higher amounts of input with higher quality to their infants since they may think that their infants have good competence in language and comprehend what is said easily. Third, given the large body of empirical evidence that there is a close relation between maternal verbal input and infants' language skills (e.g., Anderson et al., 2021), we expected that the quantity and quality of maternal verbal input would be associated with infants' overall receptive vocabulary scores.

Method

Participants

This study was part of a larger longitudinal study that examines Turkish-learning infants' language and communication, social, and cognitive development at eight monthly time points between 8 and 18 months. All infants were full-term, typically developing, and monolingual. In the current study, the participants were 34 mother–infant dyads (21 girls) who completed all our target measures: looking while listening, Turkish Communication Development Inventory-I (TCDI-I), and free play at 14 months. The mean age of the infants was 14.42 months (*SD* = 13.2 days) at the first time point of the current study. All parents were mothers. We used the years of education as the metric of SES. The sample was diverse regarding maternal years of education: 11.8% of mothers completed primary education (5 years, $n = 4$), 17.6% secondary education (8 years, $n = 6$), 26.5% high school (∼11 years; $n = 9$), 29.4% university (∼15 years, $n = 10$), and 14.7% completed higher education (Master's or PhD level, ∼17–22 years, $n = 5$).

Measures

LWL paradigm

To test infants' word comprehension via direct measurement, we used the LWL paradigm (Fernald et al., 2008) using the Tobii T120 eye tracker. Infants were presented with a series of 32 trials where two objects (one distractor and one target) were displayed on a screen. In each trial, a female native speaker vocalised a sentence ending with a familiar target noun, which is the label of the target object. During this task, infants sat on the mothers' lap across the screen, and mothers were instructed not to look at the screen. Infants watched a 5-minute video of 32 trials, each lasting 7 seconds. For each trial, infants were shown a pair of pictures (one distractor and one target) for 2 seconds; then they heard a directing sentence, including the label of the target picture, vocalised by a female native speaker: "Where's the baby? Let's look at that" for 1 second. The location of the target picture (left or right) on the screen was changed to ensure counterbalance across trials. Eight nouns were used, each once presented as the target and once as the distractor.

For these eight nouns selected, we adopted and made minor changes to the original vocabulary list of the LWL task (Fernald et al., 2008) to ensure equal syllable length for each pair. The eight target nouns were familiar to children in this age range (*kedi–bebek*, *kitap–balon*, *köpek–balık*, *araba–telefon*; cat–baby, book–balloon, dog–fish, car–phone;

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respectively). During the task, infants' eye movements were recorded as a video via the eye tracker while watching the trials. These videos obtained from the eye tracker have the default fixation algorithm of Tobii Studio (Olsson, 2007) to detect infants' eye movements on the screen (see Figure 1). ELAN software (Sloetjes & Wittenburg, 2008) was used to code the data. LWL task is often used to measure infants' lexical processing efficiency (LPE) with accuracy (looking time to the target) and reaction time (from distractor to target picture) scores by calculating proportion across all trials. However, the current study is not interested in infants' LPE but instead focuses on infants' word comprehension in each word. To measure infants' word comprehension performance for each word, we adopted the LWL task according to Valleau et al.s' (2018) task structure (see Figure 3). In each trial, during the baseline phase, picture pairs were presented without auditory stimuli. While during the query phase, infants heard the "where is the …" statement, they heard the target picture's label during the response phase. We coded infants' looking time to the target and distractor pictures to calculate their looking time proportion to the target picture during the baseline and response phases. Since a previous study by Reznick et al. (1990) showed that a 15% increase in looking preference reliably indicates word comprehension, we used this criterion in our coding. Specifically, we coded for a 15% increase in the response phase compared with the baseline phase across four trials for each target word. For each target word, if infants showed a 15% increase in more than half of the valid trials, we coded the target word as comprehended by the infant. Valid trials were those in which infants did not look away from the screen during the baseline phase, as this would make it impossible to calculate a 15% increase.

Turkish Communication Development Inventory-I

We used the Turkish version of MacArthur-Bates CDI (TCDI; Aksu-Koç et al., 2019) to test infants' receptive vocabulary scores at 14 months. TCDI-I is used to assess receptive and expressive language and early communicative behaviour of infants aged 8-16 months

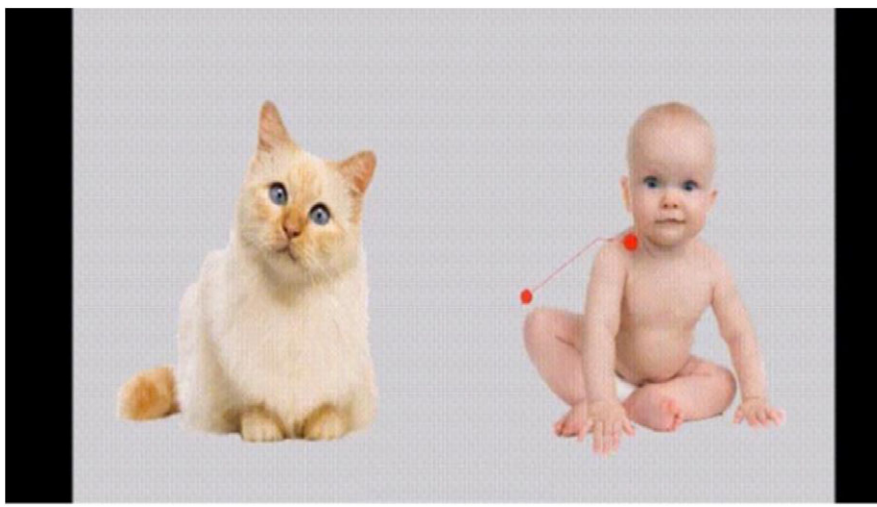

Figure 1. Example screen of a trial in the LWL task.
Note. Red points represent the infant's fixations on the screen.

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based on parental reports. The TCDI-I consists of 418 items to measure infants' expressive and receptive vocabulary. However, only the receptive vocabulary scores were used in this study since the variance of expressive vocabulary scores is less in this age range (Walle & Campos, 2014). We also used the TCDI-I as a measurement to detect mothers' underestimations and overestimations regarding their infants' word comprehension for the eight words in the LWL task.

Free play

To assess the quality and quantity of maternal verbal input to their infants, we used a free-play session in which infants and mothers participated during a 5-minute period in the laboratory (see Figure 2). The dyad was given a basket of 12 age-appropriate toys, and

Figure 2. Free play session.

	Baseline Phase	Query Phase	Response Phase
Visual Stimuli			
Duration	1500 ms	1000 ms	1500 ms
Auditory Stimuli	-	Where is the	Baby

Figure 3. Structure of one representative trial, arrayed from left to right.

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mothers were asked to play with their infants as if they were at home. The toys included a drum with two sticks, a house, a tower puzzle, a rabbit, a wheel, two ships, two sleigh bells, a carrot, a plane, and a toy camera.

Procedure

Mother–infant dyads participated in the study in a university laboratory. Since the study is part of a larger longitudinal project, the total duration of the testing at each time point was around one and a half hours. The mothers first gave informed consent and filled out the demographic form (e.g., birthdate of children, siblings, language exposure, and parents' education level) when the infants were 8 months old. At 14 months, mothers and infants participated in the LWL session, followed by five other tasks lasting ~40 minutes in total and then free-play sessions. Lastly, mothers were asked to fill out the TCDI-I. The study was conducted in line with the guidelines of the Declaration of Helsinki. All procedures in this study were approved by the [Koç University] Committee on Human Research.

Data coding

Mothers' estimations

As described in the LWL paradigm subheading, we coded infants' looking time to the target and distractor pictures to calculate their looking time proportion to the target picture during the baseline and response phases and whether there was a 15% increase in the response phase compared with the baseline phase. For each target word, if infants showed a 15% increase in more than half of the valid trials, we coded the target word as comprehended by the infant. Then, we calculated mothers' estimations by comparing maternal reports via TCDI-I and infants' LWL performances for these eight words in four categories. First, *accurate estimation of comprehension* refers to the mother's reporting as "comprehends" the related word matched with the infant performing as comprehending that word. In the same vein, *accurate estimation of non-comprehension* refers to the mother's reporting as "does not comprehend" the related word matched with the infant performed as not comprehending that word. *Overestimation* refers to the mother's reporting as "comprehends" the related word, although the infant performed as not comprehending that word. Finally, *underestimation* refers to the mother's reporting as "does not comprehend" the related word, although the infant performed as comprehending that word. We calculated the proportion of mothers' accurate estimation of comprehension and underestimation scores for the words that infants performed as comprehending that word. We calculated the proportion of mothers' accurate estimation of non-comprehension and overestimation scores for the words that infants performed as not comprehending that word yet. We calculated four scores of estimations, two of which are used for our analyses (i.e., underestimation and overestimation). Detailed examples of all four scores are depicted in Table 1.

Quantity and quality of maternal verbal input

Mothers' talk during the free-play session was transcribed and organised by following Berman and Slobin's (1994) convention that each line contained a "verb clause." Berman

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Table 1. Example of a mother's estimation codings and calculations about her infant's word comprehension

Target word	Maternal report (0 = does not comprehend, 1 = comprehend)	Infant's performance (0 = not 15% increase in looking time at target, 1 = 15% increase in looking time at target)	Accurate estimation of non-comprehension (mother = 1, infant = 1)	Accurate estimation of non-comprehension (mother = 0, infant = 0)	Overestimation (mother = 1, infant = 0)	Underestimation (mother = 0, infant = 1)
Baby	1	1	1	0	0	0
Balloon	0	1	0	0	0	1
Dog	1	1	1	0	0	0
Car	1	1	1	0	0	0
Book	0	0	0	1	0	0
Cat	0	1	0	0	0	1
Phone	1	0	0	0	1	0
Fish	0	0	0	1	0	0
Total			3	2	1	2
Proportion of estimation (%)			0.6	0.67	0.33	0.4

and Slobin (1994) defined a clause as "any unit that contains a unified predicate … expressing a single situation (activity, event, or state)" (p. 660).

To index the quantity of maternal verbal input, we calculated the number of words and number of clauses used by mothers during free-play sessions. For the quality of maternal verbal input, we coded mothers' lexical diversity, which refers to the number of different word types used during the 5-minute free-play session. A word type is a unique form of the word, where variations of roots with different suffixes count as different types. In Turkish, the word roots can take inflectional or derivational suffixes. Inflectional forms refer to different grammatical forms of the same word, such as singular or plural nouns (oyuncak vs. oyuncak-lar; "toy" vs. "toys") or different verb tenses (oyna-r vs. oyna-dı; "play" vs. "played"). Derivational form refers to words derived from the same root but have different meanings, such as "colour" vs. "colour-ful" (renk vs. renk-li). In other words, "play," "player," and "playing" are counted as different words in terms of lexical diversity.[1]

In addition, we coded linguistic complexity based on the established coding of previous studies (e.g., Aktan Erciyes, 2019; Kızıldere et al., 2022). Accordingly, we coded predicatives (main clauses), simple clauses, complex clauses, and the percentage of complex clauses to total clauses. A predicative is part of a clause that supplements the subject or object with a verb. A clause with only one predicative was coded as a simple clause. Complex clauses were coded if there was a combination of main clauses and complex structures, such as adverbials and relative clauses, conjunctions combining two clauses meaningfully, conditions (i.e., if-then statements), or reported speeches in the main clause. To measure the quality of maternal input, we calculated the linguistic complexity of mothers' verbal input by taking the proportion of complex clauses with respect to the total number of clauses. Two independent coders coded the linguistic complexity score for the reliability analysis. A trained research assistant coded the linguistic complexity of all participants, while the first author coded 20% (n = 7) of the total participants. Intraclass correlations were high among the two coders: Cronbach alphas ranged from .97 to .99.

Results

The research questions in this study were as follows: (1) Are mothers' under and overestimations regarding their infants' word comprehension associated with SES backgrounds (i.e., maternal years of education)? (2) Are mothers' overestimations and underestimations associated with the quality and quantity of their verbal input? (3) Is there a relation between mothers' verbal input and infants' receptive vocabulary skills?

Preliminary analyses

Since previous studies demonstrated sex differences in maternal behaviour (e.g., Clearfield & Nelson, 2006) and infants' vocabulary size (e.g., Bleses et al., 2008; Eriksson et al.,

[1]We coded lexical diversity in an additional way to account for only different derivational forms, coding mothers' lexical diversity by counting derivational forms as different words while counting inflectional forms as the same words. For example, "toy" and "toys" are counted as one word, and "colour" and "colourful" are counted as two different words. Our results remained the same as the results with initial coding of lexical diversity.

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2011), for control purposes we compared parents' quantity (number of words and number of clauses) and quality (number of different words and linguistic complexity) of verbal input toward infants and infants' receptive vocabulary across infants' sex. Because of the unbalanced gender distribution (21 girls, 13 boys) in the sample, a Shapiro–Wilk test was performed and showed that the distribution of sex departed significantly from normality ($W = 0.617$, $p < 0.001$). Thus, we used Mann–Whitney U test as a non-parametric test to investigate sex differences. Mothers' number of words, number of clauses, lexical diversity and linguistic complexity did not differ across sex ($Z = -1.896$, $p = .060$; $Z = -1.754$, $p = .082$; $Z = -1.65$, $p = .074$; $Z = -.074$, $p = .944$; respectively). We also compared infants' overall receptive vocabulary scores across infants' sex, and we did not find sex differences in infants' vocabulary scores ($Z = -.408$, $p = .70$). In addition, we found differences in mothers' estimation types regarding their infants' word comprehension (Table 2). Mothers' overestimations were significantly higher than their accurate estimations on comprehension ($M = .603$, $SD = .473$; $t(33) = 3.32$, $p = .002$, Cohen's $d = .569$) and non-comprehension ($M = .167$, $SD = .234$; $t(33) = 8.28$, $p = .000$, Cohen's $d = 1.419$), as well as underestimations ($M = .103$, $SD = .269$; $t(33) = 9.50$, $p = .000$, Cohen's $d = 1.629$). Also, their accurate estimations of comprehension were significantly higher than their accurate estimations of non-comprehension ($t(33) = 7.47$, $p < .00$, Cohen's $d = 1.28$) and underestimations ($t(33) = 4.74$, $p = .000$, Cohen's $d = .812$). Finally, there were no significant differences between their accurate estimations on non-comprehension and underestimations. We did not find sex differences in mothers' accurate estimations of comprehension and non-comprehension, underestimations, and overestimations ($Z = .249$, $p = .83$; $Z = -.111$, $p = .82$; $Z = 1.103$, $p = .36$; $Z = .111$, $p = .82$; respectively). Next, we performed correlations (Table 3). Maternal years of education did not correlate with input quantity (number of words and number of clauses) and input quality (linguistic complexity). However, there was a significant and positive correlation between parental years of education and their lexical diversity $r(32) = .291$, $p = .022$.

Furthermore, to test our second research question, we examined the association between maternal years of education and their estimations. Correlation analysis demonstrated that mothers' years of education neither correlated with their underestimations nor overestimations regarding their infants' word comprehension (Table 3).

Table 2. Descriptive statistics for mothers' verbal input, estimations, and infants' receptive vocabulary

Measure	*M*	*SD*	Min.	Max.
Mothers' TNoW	185.97	108.50	22	395
Mothers' total clauses	62.44	39.75	8	144
Mothers' linguistic complexity	0.05	0.05	0	0.15
Mothers' lexical diversity	69.60	35.71	11	126
Accurate estimation on comprehension (%)	0.60	0.47	0	1
Accurate estimation on non-comprehension (%)	0.17	0.23	0	0.80
Underestimation (%)	0.10	0.27	0	1
Overestimation (%)	0.83	0.23	0.20	1
Infants' receptive vocabulary scores	183.60	96.37	37	418

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Table 3. Correlations between variables

Variables	1	2	3	4	5	6	7	8
1. Maternal years of education	1							
2. Number of Words	.191	1						
3. Total clause	.186	.944***	1					
4. Lexical diversity	.391*	.883***	.821***	1				
5. Linguistic complexity	.190	.158	.063	.251	1			
6. Overestimation	.188	.507**	.421**	.536**	.347*	1		
7. Underestimation	−.124	−.092	−.260	−.346*	−.331	−.541***	1	
8. Receptive vocabulary at 14 m	−.041	−.065	.005	−.057	−.160	.373*	−.358*	1

*<.05
**<.01
***<.001

Table 4. Concurrent relations between mothers' estimations and their number of words

Predictors	β	p	R^2	ΔR^2	F-Change
Step 1		.278	.037	.007	1.217
Maternal education years	.191	.278			
Step 2		.532	.040	−.022	.105
Maternal education years	.189	.291			
Infants' receptive vocabulary at 14 m	−.057	.748			
Step 3		.014*	.344	.252	6.662**
Maternal education years	.064	.684			
Infants' receptive vocabulary at 14 m	−.309	.074			
Underestimation	−.093	.654			
Overestimation	.558	.007**			

*<.05
**<.01
***<.001

Relations between mothers' estimations and input

To test our third question of whether mothers' estimations regarding their infants' word comprehension are associated with their input quantity and quality, we conducted four separate hierarchical regression analyses, taking quantity (i.e., number of words and number of clauses) and quality (i.e., lexical diversity and linguistic complexity, separately) measures as outcome variables. We conducted the first hierarchical linear regression analysis by taking mothers' number of words as the outcome variable, including maternal years of education and infants' overall receptive vocabulary scores at 14 months as a

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Table 5. Concurrent relations between mothers' estimations and their number of clauses

Predictors	β	p	R^2	ΔR^2	F-Change
Step 1		.293	.034	.004	1.141
Maternal education years	.186	.293			
Step 2		.579	.035	−.028	.005
Maternal education years	.186	.300			
Infants' receptive vocabulary at 14 m	.013	.944			
Step 3		.057	.263	.162	4.498*
Maternal education years	.077	.684			
Infants' receptive vocabulary at 14 m	−.197	.074			
Underestimation	−.049	.654			
Overestimation	.504	.007**			

*<.05
**<.01
***<.001

control variable, and mothers' under and overestimations as predictors. We added maternal education years as a control variable in the first step, receptive vocabulary scores in the second step, and mothers' under and overestimations in the third step. Table 4 presents the model statistics. The models at the first and second steps were not significant in explaining any variance, $F\,(1, 32) = 1.217$, $p = .278$; $F\,(2, 31) = .644$, $p = .532$; respectively. However, the inclusion of mothers' under and overestimation scores improved the model significantly, $\Delta R^2 = .304$, $F\,(2, 29) = 6.732$, $p = .004$. The model in the third step significantly explained 34% of the total variance, $F\,(4, 29) = 6.662$, $p = .014$. Mothers' overestimations emerged as a significant predictor for their number of words, $\beta = .558$, $p = .007$. As mothers show more overestimations of their infants' word comprehension, mothers' number of words they provide for their infants increases.

We conducted the second hierarchical linear regression analysis by taking mothers' number of clauses as the outcome variable and following the same steps as in the first hierarchical linear regression model. Table 5 presents model statistics. The models at the first and second steps were not significant in explaining any variance, $F\,(1, 32) = 1.141$, $p = .293$; $F\,(2, 31) = .05$, $p = .579$; respectively. The third step of the model was marginally significant $F\,(4, 29) = 4.498$, $p = .057$ and overestimation was a significant predictor for the use of several clauses, $\beta = .504$, $p = .007$.

We conducted the third hierarchical linear regression analysis by taking mothers' linguistic complexity as the outcome variable and following the same steps as in the previous hierarchical linear regression models. We used square root transformation to the outcome variable (i.e., linguistic complexity) since the residuals were not normally distributed (e.g., Pek et al., 2018). Table 6 presents model statistics. The models at steps 1 and 2 were insignificant in explaining any variance, $F\,(1, 32) = 1.200$, $p = .281$; $F\,(2, 31) = .764$, $p = .388$, respectively. However, the addition of mothers' under and overestimation scores improved the model significantly, $\Delta R^2 = .181$, $F\,(2, 29) = 4.442$, $p = .021$. The model in the third step significantly explained 28% of the total variance, $F\,(4, 29) = 4.442$, $p = .043$. However, neither underestimation nor overestimation was a significant predictor for their linguistic complexity $\beta = -.238$, $p = .150$; $\beta = .319$, $p = .113$; respectively.

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Table 6. Concurrent relations between mothers' estimations and their linguistic complexity

Predictors	β	p	R^2	ΔR^2	F-Change
Step 1		.281	.036	.006	1.200
Maternal education years	.190	.281			
Step 2		.388	.059	−.001	.764
Maternal education years	.184	.300			
Infants' receptive vocabulary at 14 m	−.152	.389			
Step 3		.043	.279	.181	4.442*
Maternal education years	.079	.627			
Infants' receptive vocabulary at 14 m	−.377	.039*			
Underestimation	−.283	.150			
Overestimation	.319	.113			

*<.05
**<.01
***<.001

Table 7. Concurrent relations between mothers' estimations and their lexical diversity

Predictors	β	p	R^2	ΔR^2	F-Change
Step 1		.022*	.153	.126	5.762
Maternal education years	.391	.022*			
Step 2		.075	.154	.100	.060
Maternal education years	.389	.025*			
Infants' receptive vocabulary at 14 m	−.041	.808			
Step 3		.001***	.445	.368	7.589**
Maternal education years	.264	.073			
Infants' receptive vocabulary at 14 m	−.288	.071			
Underestimation	−.0135	.428			
Overestimation	.520	.005**			

*<.05
**<.01
***<.001

We conducted the fourth hierarchical linear regression analysis by taking mothers' lexical diversity as the outcome variable and following the same steps as in the previous hierarchical linear regression models. Table 7 presents model statistics. The models at steps 1, 2, and 3 were significant F (1, 32) = 5.762, p = .022; F (2, 31) = .060, p = .025; F (4, 29) = 7.589, p = .001. The model in the third step significantly explained 37% of the total variance. Mothers' overestimations were a significant predictor of their lexical diversity β = .520, p = .005. As they tend to overestimate their infants' word comprehension more, the lexical diversity increases.

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Since our sample consisted of 34 mother–infant dyads, we performed a post hoc sensitivity analysis using the G*Power software package (Faul et al., 2007) to inspect whether the statistical power was sufficiently high to detect the effect sizes found in the present study. Sensitivity analysis demonstrated a power of .95 (R^2 = .446) for lexical diversity, above the widely accepted power level of .80, and .74 (R^2 = .344) for number of words, which approximates the power level of .80 typically desired in psychological sciences. Considering the practical and methodological challenges in infant research, particularly with equipment like eye-tracking, this power value appears acceptable.

Relation between mothers' verbal input and infants' receptive vocabulary

To test our last research question, we ran two hierarchical regression analyses so that we could overcome the collinearity issue arising from the correlation between input measures. In both regression analyses, infants' overall receptive vocabulary scores were the outcome variable, and maternal years of education were the control variable. For the first model, the mothers' number of words and lexical diversity were added as potential predictors. The model in the first and second steps was not significant in explaining any variance F (1, 32) = .054, p = .817; F (3, 30) = 056, p = .983; respectively. Neither the number of words nor lexical diversity was a predictor of their infants' receptive vocabulary skills. The summary of these regression analyses can be seen in Table 8. For the second model, the mothers' number of clauses and the linguistic complexity were added as potential predictors. The model in the first and second steps was not significant in explaining any variance F (1, 32) = .054, p = .817; F (3, 30) = 267, p = .849; respectively. Neither the number of clauses nor the linguistic complexity was a predictor of their infants' receptive vocabulary skills. The summary of these regression analyses can be seen in Table 9.

Discussion

Literature demonstrated that children's early language skills play a crucial role in shaping their later life regarding cognitive, academic, and social skills (e.g., Agostin & Bain, 1997; Wade et al., 2014). A significant factor influencing early language skills is the quantity and quality of input parents provide (e.g., Anderson et al., 2021). Most studies have relied on

Table 8. Concurrent relations between mothers' number of words and number of different words and infants' receptive vocabulary

Predictors	β	p	R^2	ΔR^2	F-Change
Step 1		.817	.002	−.030	.054
Maternal education years	−.041	.817			
Step 2		.983	.005	−.094	.056
Maternal education years	−.040	.581			
Number of words	−.096	.432			
Lexical diversity	.0442	.470			

* <.05, ** <.01, ***<.001

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Table 9. Concurrent relations between mothers' number of clauses and linguistic complexity and infants' receptive vocabulary

Predictors	β	p	R^2	ΔR^2	F-Change
Step 1		.817	.001	−.029	.054
Maternal education years	−.041	.817			
Step 2		.756	.038	−.057	.570
Maternal education years	−.014	.939			
Total clauses	.017	.925			
Linguistic complexity	−.158	.395			

* <.05, ** <.01, ***<.001

indirect measurement tools, such as parent reports (e.g., MB-CDI, Fenson et al., 1994), to assess early language abilities rather than direct measurements. In examining the relationship between parent reports and direct assessments of early language, some studies established that mothers often make under or overestimations when reporting their infants' word comprehension levels. But, whether mothers' estimations affect the verbal input provided to their infants is unknown. The current study investigated mothers' under and overestimations of their infants' word comprehension and its relation to their verbal input, especially across diverse SES backgrounds (i.e., maternal years of education). We also investigated the relationship between the quantity and quality of mothers' input and infants' receptive vocabulary skills. Our results showed that mothers might estimate their infants' word comprehension in ways that do not match their performance in a looking-while-listening (LWL) task regardless of their SES backgrounds. Furthermore, mothers' overestimations are associated with the quantity and quality of their verbal input. The results did not show an association between maternal verbal input and infants' receptive vocabulary skills.

We expected that mothers' SES backgrounds (i.e., maternal years of education) might be negatively associated with their overestimations regarding their infants' word comprehension in line with previous studies (e.g., Reese & Read, 2000). One possible explanation is that less educated mothers may have difficulty distinguishing whether their infants comprehend a word, and then they are more likely to overestimate their infants' language abilities. However, results did not show any association between mothers' underestimations and overestimations, and their years of education. Our results suggest that both lower- and higher-educated mothers show similar patterns in terms of estimations regarding their infants' word comprehension. This might be because of several reasons: First, this might be because the infants' overall receptive vocabulary was not associated with maternal education years, and for those receptive vocabulary levels, mothers' estimations might be similar. Second, around 14 months of age, infants are still developing their receptive and expressive vocabulary. During these months, mothers might be doing over and underestimations similarly regardless of their SES background. Finally, factors aside from maternal education might play a role in mothers' estimation. For instance, maternal responsiveness and sensitivity (Tamis-LeMonda et al., 2001) might be one factor closely related to these estimations.

Our second hypothesis was that mothers' estimations would be related to their verbal input. Specifically, we expected that mothers who *underestimated* their infants' word comprehension would provide a lower input in quantity and quality to their infants. On

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the contrary, we expected that mothers who *overestimated* their infants' word comprehension would produce higher amounts of input with higher quality to their infants. In line with our hypothesis, mothers' overestimations were positively associated with their number of words and a number of different words. As mothers overestimated their infants' word comprehension more, the input quantity (i.e., the number of words) and quality (i.e., lexical diversity) increased. The regression model was marginally significant for the relations between mothers' overestimations and their number of clauses. In addition, our results showed direct correlations, such that mothers' overestimations were positively correlated with their number of clauses. These findings might indicate mothers' sensitivity to their infants' language level. Supporting this argument, previous studies demonstrated that mothers adopt their verbal input according to their children's language level. For example, Fusaroli et al. (2019) showed that children's earlier word types and tokens predict mothers' later MLU and word types. In addition, Huttenlocher et al. (2010) demonstrated that children's earlier lexical diversity predicts their mothers' later lexical diversity. Here, we present evidence that infants' word comprehension, as estimated by their mothers, predicted mothers' quantity and quality of verbal input. It is possible that mothers adjust their input based on what they infer their children's receptive vocabularies are like. Mothers' overestimations of their infants' word comprehension mean that mothers think that their infants comprehend what is said easily, leading to higher amounts of input during interactions.

Conversely, our regression model did not provide evidence for the association between mothers' overestimations and their linguistic complexity. It is also possible that mothers who believe their child has a higher level of comprehension may speak less, allowing the child to contribute more to the conversation. These alternative explanations suggest that the relationship between maternal estimations and verbal input may not be one-sided and needs further investigation into these dynamics. In addition, our regression models did not provide evidence for the relationship between mothers' underestimations and their input quantity and quality, even though there were direct correlations among them. This might be partly because of the choice of words to test in the LWL task. The word list consisted of words that infants were frequently exposed to in daily life and thus were expected to comprehend (Tekcan & Göz, 2005). This might lead mothers to usually report that their infants comprehend the words, and the task might fall short of detecting underestimations.

Our last hypothesis was that the quantity and quality of maternal verbal input would be correlated with infants' overall receptive vocabulary scores in line with the existing empirical evidence (e.g., Hart & Risley, 1995; Pan et al., 2005; Rowe, 2000). Our results demonstrate that neither the quantity nor the quality of mothers' verbal input was related to their infants' receptive vocabulary. There might be several reasons why we did not find associations between infants' receptive vocabulary and maternal input quantity and quality. First, mothers' input may not fully align with the language development needs of infants. Earlier research indicates maternal scaffolding, characterised by rich and sophisticated verbal input beyond the infants' language level, improves language outcomes. For instance, mothers' use of uncommon words predicts better vocabulary size in preschool years (Weizman & Snow, 2001). As argued before, an optimal input to infants' language development may be the input based on children's existing language and shaped by developing language competence (Jones & Rowland, 2017; Kızıldere et al., 2022). In our study, mothers' input was based on their overestimations regarding their infants' word comprehension competence, not infants' actual competence. Therefore, mothers' input might not be the optimal input aligned with their infants' communicative needs. However, because of our restricted sample size, we could not perform more sophisticated analyses, such as mediation analyses, to demonstrate overall relations between mothers'

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estimation types, their input, and infants' vocabulary size. Therefore, the lack of support for this argument partly results from sample size issues. Yet, the findings might inspire future studies to investigate how mothers' verbal input affected by their estimations corresponds to infants' word-learning needs and processes.

Second, child-level factors such as their social and cognitive skills may play an important intermediary role in the relation between maternal input and vocabulary development. For example, understanding social-communicative or sociopragmatic cues has a significant role in language development (e.g., Canfield & Saudino, 2016). Infants also learn to shift their attention according to the nonverbal communicative cues of others. They begin to follow others' gaze around 3–6 months (Behne et al., 2005), and others' pointing around 9–12 months (Deák et al., 2000; Flom et al., 2004). Moreover, infants can even use others' emotional expressions to understand the referent of a novel word (Tomasello et al., 1996). Understanding such social-pragmatic cues may provide additional information related to words and thus may render parental input more beneficial to their vocabulary development. Consequently, individual differences across infants' skills in understanding social-communicative cues, which we did not examine in the current study, might moderate the relation to maternal verbal input and language development. Future research may examine whether individual differences in infants' ability to interpret social-communicative cues moderate the relationship between maternal input and vocabulary development. Studies could provide more nuanced insights into the mechanisms underlying early vocabulary skills by incorporating observational and experimental measures of infants' understanding of social-communicative or sociopragmatic cues such as gaze-following, pointing, and responsiveness to emotional expressions.

Third, the non-significant association between verbal input and infants' receptive vocabulary might be because of methodological issues. In a recent meta-analysis study, Anderson et al. (2021) investigated moderators of the relations between verbal input quantity and quality and child language outcomes. They found a larger effect size when the mothers' input was measured in naturalistic settings than in free-play sessions. They also found that the duration of the observation was a significant moderator of the relation between input and child language outcome. Specifically, longer observations were related to a larger effect size. Our data on maternal verbal input during the 5-minute free-play sessions revealed notable variation among mothers. Descriptive statistics indicated a wide range in the input measures, suggesting considerable variability in mothers' input provided to their infants within the observed time frame. However, even though the 5-minute free-play sessions might be acceptable to reveal the relation between mothers' overestimation/underestimations and their input quantity and quality, it might be non-representative to test relations to language outcomes. This short duration may not capture the full range of natural interactions, potentially affecting the observed association between input characteristics and receptive vocabulary. In addition, the cross-sectional design might be responsible for the non-significant result. In Anderson et al.'s meta-analysis (Anderson et al., 2021), the study design was found to be a significant moderator of the relation between verbal input quantity and child language outcome. Specifically, longitudinal designs yielded larger effect sizes compared with cross-sectional designs. As the authors suggested, the quantity of verbal input may accumulate throughout the development rather than simultaneously.

One limitation of the current study is the paradigm we used to measure infants' word comprehension directly. We used the LWL paradigm specifically designed to measure infants' LPE. This task consists of eight familiar words that infants are likely to comprehend at this age. The small number of words that are likely to be comprehended by 14-month-old infants limits the measurement of parents' estimations. This may have caused parents to think that their infants easily comprehend those words, and thus, they

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overestimate more than underestimate their infants' word comprehension. The fact that parents tend to show more overestimations leads to low variance in their estimation rates. Future studies should examine parents' estimations by comparing their reports and infants' performances based on a large number of and more diverse sets of words. On the other hand, mothers may sometimes overestimate or underestimate their infants' word comprehension, while at other times, their estimations may be accurate. These estimations can be influenced by various factors, such as the type of vocabulary skill being assessed (comprehension or production), the child's age, and the child's overall language development level (e.g., Bennetts et al., 2016; Lopez-Perez et al., 2024). In this study, however, we focus on whether the mothers' years of education are associated with their overestimations or underestimations for specific words and how these estimations relate to the verbal input they provide to their infants. Future studies may investigate other potential factors influencing maternal estimations, such as cultural differences, maternal beliefs about language development, or infants' communicative skills, to provide a more comprehensive understanding of these dynamics.

Overall, these results are important for future studies. First, our results demonstrated that regardless of SES backgrounds, mothers tend to overestimate and underestimate their infants' word comprehension. Future studies should take these findings into account when selecting measures to assess child language, especially for this early developmental stage. Parent-reported language measures, especially CDI, are the most common way to assess early language skills for studies with limited time and resources. Parents should be given detailed instructions on distinguishing whether a word is comprehended or not by their infants. Moreover, to our knowledge, this is the first study to investigate the association between mothers' underestimations and overestimations and their verbal input quantity and quality. The finding is crucial, especially for intervention studies, such as the study highlights how parents can observe and evaluate their infants' language skills more accurately and provide "optimal input" to better language growth rather than training parents only in the importance of verbal input for early language development.

In conclusion, this study presented one of the first pieces of evidence on mothers' estimations and their effect on mothers' verbal input and infants' vocabulary development. Mothers often estimate their infants' word comprehension differently than their infants' performance in more direct measurements. Their overestimation positively predicts their verbal input quantity (i.e., number of words) and quality (i.e., lexical diversity). These findings suggest that mothers might use their estimations regarding their infants' word comprehension when providing verbal input to their infants. Given we found no concurrent association between maternal input quantity and quality and infants' receptive vocabulary in these early months, infants' understanding of sociopragmatic cues in child-directed interaction should also be researched as a contributing factor.

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