Published in final edited form as:
Child Dev. 2023 March ; 94(2): 478–496. doi:10.1111/cdev.13872.

Talking to talkers: Infants' talk status, but not their gender, is related to language input

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Abstract

Prior research points to gender differences in some early language skills, but is inconclusive about the mechanisms at play, providing evidence that both infants' early input and productions may differ by gender. This study examined the linguistic input and early productions of 44 American English-learning infants (93% White) in a longitudinal sample of home recordings collected at 6–17 months (in 2014–2016). Girls produced more unique words than boys (Cohen's d=0.67) and this effect grew with age, but there were no significant gender differences in language input (d=0.22–.24). Instead, caregivers talked more to infants who had begun to talk (d=0.93–.97), regardless of gender. Therefore, prior results highlighting gender-based input differences may have been due, at least partly, to this talking-to-talkers effect.

Keywords

cognitive development; language acquisition; gender

Children vary in the rate at which they acquire linguistic skills, and these individual differences can have long-term impacts on various behavioral and education outcomes (Duncan et al., 2007; Morgan, Farkas, Hillemeier, Hammer, & Maczuga, 2015; Petersen et al., 2013). For example, Bleses, Makransky, Dale, Højen, and Ari (2016) found that 1- to 2-year-olds with larger vocabularies went on to have better academic achievement 10 years later when they were in 6th grade. Children's early language skills, such as vocabulary, may have such long-term effects because they are foundational to numerous other skills. Strong language skills can help children learn to read (Perfetti & Stafura, 2014), learn mathematics (LeFevre et al., 2010), regulate their emotions (Cole, Armstrong, & Pemberton, 2010), and engage with peers (Braza et al., 2009; Menting, van Lier, & Koot, 2011). In this way, early language skills affect many domains of life, and language difficulties can be detrimental throughout childhood and beyond.

One factor associated with differences in language ability is child gender. Across a wide range of metrics, girls have generally been found to have linguistic skills superior to age-

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The data and analytic code necessary to reproduce the analyses presented in this paper are publicly accessible at https://osf.io/qkb6p/. The analyses presented here were not preregistered. Recordings are available to authorized researchers at https://nyu.databrary.org/volume/228.

matched boys (e.g., Lange, Euler, & Zaretsky, 2016). These differences are evident from the onset of speech in infancy (Kimura, 1999) and persist over time (Bornstein, Hahn, & Haynes, 2004; Voyer & Voyer, 2014). While there is some evidence that boys vocalize more than girls early in infancy (Oller et al., 2020; Sung, Fausto-Sterling, Garcia Coll, & Seifer, 2013), studies generally fail to find gender differences in vocal maturity or articulatory skills during the first year of life (Cychosz et al., 2021; Oller et al., 2020; Quast, Hesse, Hain, Wermke, & Wermke, 2016). In contrast, girls have been found to gesture, say their first words, and combine words earlier than boys (Eriksson et al., 2012; Maccoby, 1966; Özçalışkan & Goldin-Meadow, 2010), and to have larger productive vocabularies (Bornstein et al., 2004; Fenson et al., 1994; Huttenlocher, Haight, Bryk, Seltzer, & et al, 1991). For example, a typical American English-learning 2-year-old girl has a productive vocabulary of 369 words, while a typical boy can say nearly 100 fewer words at the same age, with a productive vocabulary of 272 words (based on >3000 CDIs via Wordbank, Frank, Braginsky, Yurovsky, & Marchman, 2017). Furthermore, Huttenlocher et al. (1991) found an interaction of age and gender on child language production: female infants' rate of language acquisition was faster. More specifically, girls showed more vocabulary growth at 14–26 months than their male peers (Huttenlocher et al., 1991). While the majority of research on this topic has been conducted in English-speaking American samples, a female language advantage more broadly has been found consistently across languages and cultures (Frank, Braginsky, Yurovsky, & Marchman, 2021; OECD, 2010, p. 55).

Moreover, language disorders and delays disproportionately affect boys (Chilosi, Brovedani, Cipriani, & Casalini, 2021; Paul, 1993; Rescorla, 2011; Shriberg, Tomblin, & McSweeny, 1999). Boys are at a higher risk of long-term language deficits (e.g., Specific Language Impairment, Tomblin et al., 1997) and shorter-term language delays (e.g., late talkers, Collisson et al., 2016). (However, we note that research on language delays and disorders has primarily been conducted in Western cultures, and the literature may be further skewed by an under-diagnosis of language disorders in girls.) Despite the far-reaching effects of early differences in language skills, the reasons for these gender differences in early language development are poorly understood.

One potential explanation for early gender differences in language skills is varying environmental input. That is, infant girls may be spoken to more than infant boys. Given that infants who receive more language input attain better outcomes across several linguistic skills (Huttenlocher et al., 1991; Huttenlocher, Waterfall, Vasilyeva, Vevea, & Hedges, 2010; Rowe, 2012; Weisleder & Fernald, 2013), such an input disparity could lead to the female advantage found in prior work. Indeed, a female language advantage is consistent with a gendered stereotype that language is a "female domain" in various cultures (Plante, Théorêt, & Favreau, 2009; Schmenk, 2004), which could drive caregivers to speak or respond to children differentially based on gender. Therefore, a gender difference in early language abilities could arise from early social and linguistic practices, including input quantity and quality, if the language input varies in a way that benefits girls.

Consistent with this possibility, some prior studies find that parents talk more to girls than boys in infancy and toddlerhood (Cherry & Lewis, 1976; Johnson, Caskey, Rand, Tucker, & Vohr, 2014; Leaper, Anderson, & Sanders, 1998). See Table 1. While the majority of all infants' linguistic input comes from their mothers (Bergelson et al., 2019; Johnson et al., 2014; Leaper et al., 1998), there is evidence that mothers of girls speak more than mothers of boys to their children in early infancy (Leaper et al., 1998). Moreover, there may be interaction effects of parent and child gender: some studies report that mothers, but not fathers, are more responsive to female babies than to male babies (Johnson et al., 2014). Mothers may also use different sentence structures with girls than with boys (Cherry & Lewis, 1976; Clearfield & Nelson, 2006). For example, in their analysis of parent-child play interactions with 24-month-olds, Cherry and Lewis (1976) found that mothers asked more questions and used more explanations and repetition with girls than with boys. Similarly, Clearfield and Nelson (2006) analyzed mother-child interactions in infancy and found that mothers asked more questions ("Are you going to get the ball?") of their daughters, while using more directives ("Go get the ball!") and attention-getters ("Look over here!") with their sons, even at six months of age. No differences in subsequent infant behaviors were found, leading the authors to suggest that these mothers were not responding to their infants' behaviors, nor were they causing differentiated behaviors with their gender-varying utterance types. Importantly, beyond these studies, these sentence structures have been shown to affect early language acquisition. Specifically, questions and repetitions (which Cherry and Lewis, 1976 and Clearfield and Nelson, 2006 found that girls hear more of) have been associated with larger child vocabulary (Rowe, Leech, & Cabrera, 2017) and thus are proposed to benefit early language development.

However, other research has reported conflicting results (e.g., Huttenlocher et al., 1991; Pınar, Ozturk, Ketrez, & Özçalışkan, 2021). Huttenlocher et al. (1991) examined speech to 1- to 2-year-olds in a longitudinal sample and found no differences in the amount of parental speech to sons and daughters. Furthermore, they found that the gender difference in production remained even controlling for input, suggesting that the gender difference in production was independent of language exposure (Huttenlocher et al., 1991). Other studies have even found a gender difference in the opposite direction, with boys hearing more speech than girls (Ahl, Fausto-Sterling, García-Coll, & Seifer, 2013; Laflamme, 2002; Weitzman, Birns, & Friend, 1985).

One possible reason for the conflicting results in the literature is the various methods used to measure infants' language exposure and production. For example, Johnson et al. (2014) assessed automatically-derived language estimates (from the Language Environment Analysis System, LENA) from infants at 0, 1, and 7 months of age, while Huttenlocher et al. (1991) analyzed maternal-reported child vocabulary and transcripts of a session where an experimenter was present between 14 and 26 months of age. While both approaches are valuable, their differences in infant age and sampling method limit comparison. In addition, previous studies have generally focused on either linguistic input or early production (though c.f. Huttenlocher et al., 1991), usually within a constrained age range. Thus, while various studies have examined the input and early productions of female versus male infants, direct comparisons across studies are often inconclusive or confounded by disparate study approaches.

In an effort to summarize this varied literature, Leaper et al. (1998) conducted a meta-analysis (primarily on studies of middle-class White English-speaking American families) and found significant differences in parents' speech directed to girls vs. boys. They found that mothers talked more and used more supportive language with daughters than with sons. Further, they also found that year of publication significantly moderated the gender difference in parental language: effects decreased over time by year of publication (i.e., input became more equivalent across genders). This finding, from over 20 years ago, leaves open the possibility that differences in caregivers' behavior based on child gender have changed over historical time. However, a more recent systematic review again found that parents speak differently to boys and girls (e.g., mothers of girls respond more contingently, Morawska, 2020). Notably, Morawska (2020) also highlighted the need for longitudinal studies to disentangle the effects of child gender on both parent and child behavior over time.

Complicating matters further, a growing literature suggests that the quantity and quality of language input may interact with children's age and language skill level (e.g., Bergelson et al., 2019; Huttenlocher et al., 2010; Leung, Tunkel, & Yurovsky, 2021; Snow, 1977). Therefore, it is difficult to disentangle the effects of child age, language skills, and gender on children's language input. If parents talk differently to their children depending on the child's language ability, and girls have better language abilities than boys, this could potentially account for reported gender differences in parental input.

In summary, despite a robust literature documenting early gender differences in language *skills* (particularly vocabulary), conflicting and confounded results limit our understanding of gender differences in infants' language *input*. Importantly, prior work has not disentangled the effects of child age, gender, and language ability on children's language input over time. Here, we address this gap by examining children's language input in relation to their age, gender, and language skills longitudinally within a single sample.

The Present Study

In what follows, we combine both input and production data from naturalistic home recordings within a single set of infants, spanning the time when word production begins. With this combination of data, we can analyze infants' linguistic input before and after they begin to speak, in concert with their age, gender, and measures of their early productions. Specifically, we seek to answer three questions:

1. Do female infants produce more words than male infants, even at the earliest stages of word production?
2. If so, is this gender difference readily explained by a concomitant difference in children's language input (i.e., differentiated amounts or types of nouns in speech to girls and boys)?
3. Do changes in language abilities (e.g., the onset of talking) lead to changes in language input, either alone or in interaction with age and child gender?

Based on the previous literature, we predict that female infants in our sample will show more advanced language production than males and that this effect will grow with age. The mixed evidence from prior research leaves open whether there will be differences in children's language input by gender, particularly when also considering child age and whether the child has started speaking or not (talk status). The analyses that follow will let us consider whether input differences for boys versus girls are a viable explanation for the expected female vocabulary advantage, or whether invoking age or talk status would provide a better characterization of input differences. If the input varies more as a function of children's language skill or maturity (i.e., age and/or talk status) rather than gender, this would suggest that input differences do not explain the origins of potential gender differences in vocabulary.

Method

Participants

Participants ($N = 44$; 21 girls, 23 boys) were typically-developing, monolingual English-learning infants who participated longitudinally from age 6 to 18 months. Participants were recruited from a database of local families in Rochester, NY; all eligible families were contacted regardless of demographic characteristics (i.e., no specific demographic-based recruitment was applied). 75% of mothers and 72% of fathers had a Bachelor's degree or higher. These data are part of the SEEDLingS corpus (Bergelson, 2016b, 2016a). All participants came from two-parent families. One family had same-sex parents; this participant was excluded from mother-father analyses (see "Effects of Parent Gender") but included in all other analyses.

We have opted to use the term "gender" (except when discussing other work on biological differences, such as sex hormone levels) as our analyses encompass social and behavioral differences. While the infants in this study do not yet have a developed gender identity, this reflects the gender they are being socialized with (based on their sex assigned at birth). We note that the infants' reported genders are, therefore, subject to change with time as children age and develop their own gender identity.

Procedure

Data collection took place from November 2014 to July 2016. Infants received home visits longitudinally from the ages of 6 to 17 months. Child-centered daylong audio recordings and hourlong videos recording were collected each month during this time, for a total of 12 audio- and 12 video-recordings per infant. See Bergelson and Aslin (2017) and Bergelson, Amatuni, Dailey, Koorathota, and Tor (2019) for more details about recording procedures.

Data Annotation and Aggregation

Each home recording (audio and video) was annotated by a trained human coder to mark the object words heard by and produced by the child, as well as details about them. The annotations include each object word (concrete, imageable object nouns, e.g., shoe, dog, arm) heard by or uttered by the child. We included words spoken by any talker present during the recording (e.g., mother, father, siblings, neighbor), unless otherwise noted. While the majority of input in our corpus comes from children's parents (77%; 64% from mothers), our aim is to characterize noun input from all sources, and thus we also include input from siblings, other family members, babysitters, etc. in our results.

For each object word annotated, we included its speaker and the type of utterance it occurred in: declarative, question, imperative, reading, singing, or short-phrase (utterances of < 4 words, e.g., “hi, baby!” or “red ball”). The full length of each hour-long video recording was annotated for object words in this way (i.e., the full hour). The full length of each daylong audio recording was annotated for object words (i.e., up to 16 hours) at 6 and 7 months. In later months, we annotated object words in 3 to 5 hour-long regions from each recording; these hour-long regions were subsampled to have high amounts of talking (as determined by an algorithm that created ranked hour-long subregions by weighing LENA’s CVC and CTC metrics over the entire day; code can be found online at https://github.com/SeedlingsBabylab/audiowords; the full data processing pipeline can be found here: https://bergelsonlab.gitbook.io/blab/data-pipeline). Because the amount of time annotated per daylong audio-recording varied across months, for the present input analyses, we use data from the top 3 hours of each audio recording (based on the LENA-metric ranking described above), and each video-recorded hour. Thus, all input analyses below stem from children’s combined audio and video noun input from 48 hours of recordings per child (aggregated across 12 hours of video recordings and 36 hours sampled from daylong audio recordings). See Figure 1 for overview of data annotation pipeline. This corpus includes a total of 5737 noun tokens produced by the target children and 257225 noun tokens produced by all other talkers.

For relevant analyses, we operationalized talk onset as the age in months at which each infant was first captured producing a noun in our recordings (see Moore, Dailey, Garrison, Amatuni, & Bergelson, 2019 for details on the annotation of child productions). While talk onset is difficult to measure, the age of talk onset, as observed by researchers in our recordings, does not differ significantly from the age of talk onset, as reported by parents on the CDI in this sample (Moore et al., 2019).

In the main manuscript, we analyze children’s noun input and productions as proxies for overall language input and productions. Prior work has established that concrete nouns serve as a viable proxy for all language input (Bulgarelli & Bergelson, 2020). Despite being a relatively small proportion of the words in children’s input, concrete noun counts are significantly correlated with overall adult word counts ($R = 0.73$, Bulgarelli & Bergelson, 2020). It has also been established that English-learning children’s vocabularies are dominated by nouns (Bates et al., 1994; Frank et al., 2021). In the current dataset, observed noun vocabulary is correlated with overall CDI productive vocabulary (R=.81 [.68, .89]). Noun vocabulary and overall vocabulary from the CDI were also extremely highly correlated (R=.99 [.99, > .99]).

While the focus of the present work is the lexical level (i.e., noun types and tokens in the input and in children’s productions), we include analyses of more holistic LENA-generated estimates (Adult Word Count, Child Vocalization Count, and Conversational Turn Count) in the Supplementary Materials; these automated measures from the daylong LENA audio recordings in our dataset revealed the same general pattern of results reported below.

Results

Analysis Plan

First, we assess if there are gender differences in children's early productions. We report children's language productions as observed by researchers in our audio- and video-recordings here; see Supplementary Materials for analyses of parent-reported vocabulary (via the CDI). Then, we turn to children's language experience, asking if the quantity or diversity of nouns children hear varies between boys and girls, as a potential explanation for differences in their productions. This includes the diversity and overall quantity of nouns (i.e., noun types and tokens), the utterance types nouns occur in, and if mothers and fathers speak differently to girls vs. boys. Finally, we assess if children's talker status, rather than their gender, affects their language input.

In our analyses, we primarily use t-tests and linear regressions. We use t-tests to test for an overall difference between groups (girls vs. boys) on a given metric (except in one case where proportions of utterance types are analyzed, for which we use Wilcoxon tests due to the nonnormality of proportion data). Due to the longitudinal nature of our study, we additionally utilize linear regressions to account for child age and assess language input and production measures *over time* (i.e., vocabulary growth over time, and interaction of age, gender, and talk status). When testing for interactions (i.e., child gender × parent gender; talking status × child gender), we report the results of model comparison (i.e., does an interaction improve model fit).

Unless otherwise noted, statistical tests were run over transformed data: all input type and token counts are square-root transformed and all child-produced type and token counts are log-transformed to ensure we meet the assumption of normal distributions for our statistical tests. (Non-parametric statistics, e.g., Wilcoxon tests, over raw type and token counts find the same pattern of results.) We report non-transformed group means and standard deviations for interpretability.

While the specifics of our analysis plan were not preregistered, our analyses of gender differences in word production are confirmatory, as our directional a-priori hypothesis was that girls would show advanced language relative to boys; our analyses of gender effects in the input and of talk onset are exploratory.

Early Productions

To determine if gender differences exist in infants' early productions, we first analyzed the age each infant first said a word (limiting analysis to concrete nouns) in our recordings. The age of first spoken word in our recordings was about a month earlier for female infants than for male infants ($M_{females}$=11.95 (1.90) mos, M_{males}=12.91 (2.09) mos), but this difference was not statistically significant (t(40.00) = −1.56, p = .128 Cohen's d = −0.48, [−1.09, 0.14]; see Figure 2). Although this study primarily focuses on nouns, we also assessed the age of onset for words of any lexical class and found no difference in mean age ($M_{females}$=11.62 (1.94) mos, M_{males}=11.35 (1.75) mos; p = .631). This is likely due to the high variability in the age at which children produce their first words and is limited by our sample size.

We next analyzed the number of types (i.e., unique words) and tokens (instances, i.e., total word counts) that each infant produced in total across our recordings. We found that female infants produced significantly more unique words ($M_{females}$ = 29.43 (35.90); M_{males} = 11.26 (10.80); $t(37.76) = 2.18$, $p = .036$, Cohen's $d = 0.67$, [0.05, 1.27]). However, girls did not produce more speech overall (i.e., more instances of words; $M_{females}$ = 180.48 (229.56); M_{males} = 84.65 (93.43); $t(41.28) = 1.31$, $p = .196$, Cohen's $d = 0.40$, [−0.20, 0.99]). See Figure 2. This suggests that girls in our sample are not more talkative overall, but produce a greater variety of nouns than boys do.

To investigate vocabulary growth over time, we ran a set of mixed effects linear regressions. Here, we predict the number of nouns (type and token) infants produced each month (see Supplementary Materials for an analysis of the number of *new* noun types the infants produced each month). As no child produced a word in our recordings before month 9, we include only months 9 to 17 in this analysis, but we include data from all subjects across this span (including vocabularies of 0). For both noun types and noun tokens, we compared three models:

1. log(nouns produced) ~ age in mos. + (1|subject)
2. log(nouns produced) ~ age in mos. + child gender + (1|subject)
3. log(nouns produced) ~ age in mos. × child gender + (1|subject)

Model 1 (baseline) predicted word counts (i.e., nouns produced) as a function of age in months (as a fixed effect) and infant (as a random effect). We included age as a fixed effect given its strong expected contribution to word production. We included a random effect of infant due to the longitudinal nature of our study, i.e., our multiple measures within participant. Model 2 adds child gender, and model 3 adds an interaction of child gender and age.

For noun types, while the regression results for the model including gender (model 2) showed that infant gender was a significant predictor ($\beta_{gender\text{-}males} = -0.15$, $t(42.00) = -2.25$, $p = .030$), model 2 did not provide a significantly better fit to the data than baseline (model 1) by model comparison (χ^2=1.35, $p = .245$). However, adding an interaction of age and gender (model 3) significantly improved model fit (χ^2=12.64, $p < .001$). Specifically, the interaction indicated that the increase in noun types with age was stronger for girls than boys. See Figure 3 and Table 2.

Noun tokens, on the other hand, showed a different pattern. Neither infant gender (model 2; χ^2=0.04, p.837) nor an interaction of age and gender (model 3; χ^2=3.49, $p = .062$) improved model fit over the baseline model (model 1). See Figure 3 and Table 2.

Thus, child word *types* were best predicted by model 3, which includes an interaction of child gender and age, while child word *tokens* were best predicted by model 1, which includes only child age and not gender. This suggests that female infants showed a faster *rate* of vocabulary growth in our sample; the gender difference in children's productive vocabulary (i.e., noun types, rather than noun tokens) increases across 9–17 months

Linguistic Input

Having replicated previous results showing a gender difference in early vocabulary, we turn to the language input. First, we analyzed how many words children heard (averaged across their recordings). We found no gender differences in number of noun types ($M_{females}$ = 146.94 (36.17); M_{males} = 139.29 (50.38); t(40.02) = 0.75, p = .459, Cohen's d = 0.22, [−0.37, 0.81]) or noun tokens ($M_{females}$ = 505.81 (173.72); M_{males} = (209.72); t(41.11) = 0.79, p = .435, Cohen's d = 0.24, [−0.36, 0.83]) in the children's input. See Figure 4. This suggests that parents are not speaking more to female infants than to male infants overall.

Effects of Parent Gender.—Next, we tested if mothers and fathers speak differently to girls and boys. For this analysis, we analyze only the nouns spoken by each infant's mother and father; we excluded nouns from other talkers, and excluded 1 participant with same-sex parents. Of the 515 audio recordings analyzed in this analysis, 447 included nouns spoken by both mothers and fathers, 64 did not feature fathers, and 6 did not feature mothers; there were an average of 5.98 talkers producing nouns (including all sources, e.g. talking toys, siblings, family members, etc.). Of the 515 video recordings analyzed here, 151 included nouns spoken by both mothers and fathers, 318 did not feature fathers, and 65 did not feature mothers; there were an average of 3.29 talkers producing nouns.

For both noun types and noun tokens, we ran the following model: √input noun count ~ parent gender + child gender. We find a main effect of parent gender and no effect of child gender; see Table 3 and Figure 5. This result shows that infants hear more words from their mothers than their fathers. Indeed, the majority of children's input in our naturalistic recordings comes from mothers (64.23%, compared to 12.38% from fathers). This is consistent with prior work regarding the predominance of female caretaker speech (Bergelson et al., 2019; Johnson et al., 2014; Leaper et al., 1998). That said, the density of our corpus results in a sizeable number of noun types (4937 from mothers and 2526 from fathers) and tokens (161436 from mothers and 32522 from fathers) from each parent to analyze.

Next, we added an interaction between parent and child gender to the model (i.e., √input noun count ~ parent gender × child gender). The interaction term is not significant on its own (types: b = −0.54, 95% CI [−2.49,1.41]; tokens: b = −0.90, 95% CI [−4.74,2.94]) nor does it improve model fit (types: F(1, 83) = 0.31), p = .581; tokens: F(1, 83) = 0.22 , p = .642). See Table 3. Thus, we find no evidence in support of an interaction of parent and child gender on the number of noun types or tokens in the infants' input.

Utterance Types.—Next, we examined the proportion of utterance types (declarative, imperative, question, reading, singing, or short-phrase) that nouns occurred in. We find no gender differences in the proportions of utterance types in children's input, either before talk onset, after talk onset, or overall (all ps > .05 by Wilcoxon test; see Figure 6).

Attempted Replication of Previous Findings.—Prior studies (e.g., Huttenlocher et al., 1991) often assessed language input from children's mothers only. Therefore, in order for more direct comparisons to the previous literature, we conducted two analyses using maternal input counts only. We assessed the average number of words children heard from their mothers, and found no gender difference in noun types (M_{female} = 111.04 (41.35); M_{males} = 100.30 (53.85); t(37.87) = 0.99, p = .327) or noun tokens (M_{female} = 335.30 (177.84); M_{males} = 291.44 (190.49); t(40.26) = 1.01, p = .320). Then, we assessed the numbers of words in questions and commands that children heard from their mothers. Again, we find no differences in the average proportion of commands (M_{female} = 7.38% (3.71%), M_{males} = 8.20% (5.14%), W = 229.00, p = .780 by Wilcoxon test) or questions (M_{female} = 23.05% (5.18), M_{males} = 24.71% (5.84%), W = 200.00, p = .339) addressed to boys and girls. While not considered in the original work we aimed to replicate with this analysis, the same pattern (i.e., no differences in noun types, tokens, questions, or commands) holds for the input from fathers alone (all ps > 0.4).

Effect of Talker Status

Next, we assessed whether individual infants' talk status (i.e., whether or not they have said their first noun in our recordings) has an effect on the average number of nouns they hear. Two infants (1 male, 1 female) did not produce a word in our recordings and are excluded from this analysis. Excluding their own productions, we found that infants heard more types and more tokens in their input after they themselves began talking (averaged over pre-talk onset and post-talk onset months for each infant; types: t(40) = −5.93, p < .001, Cohen's d = 0.93, [0.55, 1.29]; tokens: t(40) = −6.22, p < .001, Cohen's d = 0.97, [0.59, 1.34]). On average, infants heard 130.41 noun types in each month's recordings (i.e., 4 hours per month, across audio and video) before they started talking, compared to 157.86 noun types after they started talking. Similarly, we observed an increase in noun tokens: infants heard an average of 422.31 noun tokens in each month's recordings before they started talking, compared to 560.47 noun tokens after they started talking. 35 out of 41 infants heard more noun types and 36 out of 41 infants heard more noun tokens in their input after talk onset (both ps < .001 by binomial test). See Figure 7.

We also examined whether individual infants' talk status affects the utterance types they hear nouns in. We found that infants heard significantly more nouns in short phrases (e.g., "red ball") after they started talking (increase of 2.55%, SD = 0.04, p = .002 by Wilcoxon test, which is below a Bonferroni-corrected threshold of p=.0083, given the 6 tests conducted). See Figure 8. There were no significant changes in other utterance types (all ps > .05 by Wilcoxon test). We also find no interaction between child gender and talk status on any utterance type (all ps > .05 by Wilcoxon test).

Interaction of Age, Talk Status, and Gender

Finally, we wanted to investigate if child gender, talk status, and age interact to affect infants' language input. To do so, we ran a set of models to test for interactions of age, gender, and talk status on input noun counts. For both types and tokens, we compared two models: a model that included two-way interactions between age, gender, and talk status (√(input noun count) ~ age in mos. × talk status + child gender × talk status + age in mos. × child gender + (1|subj)); and a model that added a three-way interaction (i.e., √(input noun count) ~ age in mos. × child gender × talk status + (1|subject)). As above, we include a random effect of infant due to the inclusion of multiple timepoints per infant. For noun types, we find significant interactions between child age and talk status, as well as talk status and gender. See Table 4 and Figure 9. The age-by-talk status interaction indicates that the effect of age is stronger once infants begin talking. In contrast, the gender-by-talk-status interaction indicates that for talkers, there is a larger gender difference in input than for non-talkers. Adding a three-way interaction term does not significantly improve model fit (χ^2=0, p > .999).

We see the same pattern for noun tokens: significant interactions between age and talk status, and talk status and gender. Again, talkers who are older and talkers who are girls hear more noun tokens, and adding a three-way interaction does not improve model fit (χ^2=0, p > .999). See Table 4 and Figure 9.

Discussion

In this study, we investigated the effects of gender on children's language input and productions and aimed to disentangle the effects of age, gender, and talk status on children's language input. First, we replicated previous findings that infant girls have larger vocabularies than boys at the same age. This difference appears small but robust. However, contrary to previous findings, we find little evidence for a gender difference in language input. In our sample, girls did not hear more words than boys overall, from either parent, or within particular utterance types. Instead, we find that children's language input was strongly linked to their talk status: regardless of gender, infants heard more words once they themselves start talking.

Gender differences in early productions

Female infants in our sample produced a significantly greater number of noun types, but not tokens, than male infants. We also found that as children get older, female infants' vocabularies grew faster than male infants'. In other words, the difference between male and female infants' word production increased with age.

This result replicates Huttenlocher et al. (1991) and suggests that the gender difference in child language is not driven by "chattiness" (which would be seen in noun tokens), but instead by productive vocabulary (noun types). While boys may vocalize more than girls early in infancy (Oller et al., 2020; Sung et al., 2013), this gender difference in the number of vocalizations seems to disappear by the time children are saying words. After talk onset, girls and boys appear to be similarly vocal, but girls produce a greater variety of words. These results (i.e., equivalent noun token counts produced by girls and boys) are in line with research that finds no gender differences in overall talkativeness by word token counts in adults across various contexts (Leaper & Ayres, 2007; Mehl, Vazire, Ramírez-Esparza, Slatcher, & Pennebaker, 2007), despite a cultural stereotype that women are more talkative than men (Kaplan, 2016, p. 155).

While the work cited above suggests talkativeness doesn't vary in men and women when considering a broad range of contexts, caretaking for young children in particular does seem to be a context in which women say more than men, on average. Prior studies specifically investigating infants' input have similarly found that the majority of infants' language input comes from women (Bergelson et al., 2019; Johnson et al., 2014; Leaper et al., 1998).

For example, Bergelson et al. (2019) found that North American infants heard over twice as much speech from women (generally infants' mothers) as from men (generally infants' fathers). In this sample and in many others, women are often the primary caregivers for their children. These factors likely drive the high proportion of maternal speech in infants' input, rather than any overall difference in talkativeness between genders.

While our finding that girls produced more noun types was readily evident over the course of year two, our results regarding first word production were less robust. Namely, while the girls in our sample produced their first nouns a month earlier than the boys on average, this difference was not significant. We attribute this to both the challenges of estimating talk onset (both for parents and in observational data, c.f., Moore et al., 2019), and to our limited sample size, which limited our ability to detect relatively small effects. Future work should use larger samples to determine if there is a true effect of gender on the age of talk onset that we were unable to detect.

Although in our sample, we find the gender difference *increases* with age over the first 1.5 years, other studies find that this gender difference may fade, or even disappear, later in childhood. For example, Bornstein et al. (2004) found significant gender differences across a variety of language assessments at ages 2 to 5 years, but this difference disappeared in their study by age 6. However, other studies find evidence for gender differences in language throughout the lifespan (e.g., Kaushanskaya, Marian, & Yoo, 2011), so the duration of these differences remains unclear. That said, whether these gender differences fade with age or not, the gender difference in the incidence (and/or diagnoses) of language delays and disorders (Paul, 1993; Rescorla, 2011; Shriberg et al., 1999) and the "gender gap" in literacy abilities in school-age children (OECD, 2015; Voyer & Voyer, 2014) remain important issues.

Potential sources of a female language advantage

Turning to children's language input, we found little evidence for differences in language input to male and female infants, as we have quantified it here. However, while we measured a variety of features, there may be other differences in infants' linguistic input that our study has not captured, such as acoustic properties of child-directed speech, that may vary by gender. For instance, in some contexts mothers may use higher pitch and a wider pitch range – two key features of infant-directed speech that attract infant attention (Fernald & Kuhl, 1987) – with girls than boys (Kitamura & Burnham, 2003; Kitamura, Thanavishuth, Burnham, & Luksaneeyanawin, 2001). Similarly, while we did not find a gender difference in utterance types, there may be finer-grained differences prosodic structure to girls versus boys. These features of child-directed speech, if they vary by child gender, could potentially benefit girls' language development.

Beyond linguistic input, there may be other differences in children's early development and experience that could drive the gender difference we see in production.

Firstly, gender differences could be driven by differences in caregivers' behavior. For example, caregivers may touch, make eye contact with, and be more sensitive with girls than with boys (Lindahl & Heimann, 1997; Moss, 1967). Importantly, such caregiver behaviors may affect early language skills (Bornstein et al., 2020). Therefore, if these behaviors are mediated by gender, they could aid infant word learning differentially by gender. Conclusions regarding this possibility await further research.

Secondly, there may be gender differences in infant abilities and behaviors. For example, male infants may be more physically active than female infants (Campbell & Eaton, 1999). There may also be early gender differences in infant temperament, such as higher inhibitory control and perceptual sensitivity in girls than in boys (Else-Quest, Hyde, Goldsmith, & Van Hulle, 2006). These early behavioral tendencies could shape infant-caregiver interactions, for example, leading girls to engage in more coordinated face-to-face communication than boys (Hsu & Fogel, 2003). Relatedly, there may be differences in female infants' early social and communicative tendencies and/or abilities that allow them to take better advantage of the language input they receive. For example, there is evidence that girls may engage in more social and communicative behaviors than boys, such as joint attention (Mundy et al., 2007; Olafsen et al., 2006) and eye contact (Hittelman & Dickes, 1979; Lutchmaya, Baron-Cohen, & Raggatt, 2002). Joint attention has been found to provide beneficial word learning opportunities: In episodes of joint attention, caregivers often talk about the object that the child is attending to, thereby aiding the child's understanding of word meanings (Tomasello & Farrar, 1986). Therefore, if girls engage in more joint attention, these interactions may help girls more readily establish what the language around them refers to and boost their vocabulary growth.

Thirdly, there may be hormonal factors at play. A growing literature suggests that sex hormones influence the development of language-related brain regions. Infants' sex hormone levels are correlated with their early articulatory skills (i.e., early babbling, Quast et al., 2016) as well as their language skills later in childhood (Hollier et al., 2013; Schaadt, Hesse, & Friederici, 2015). In male infants, testosterone levels at birth (which may affect language abilities via brain lateralization, Lust et al., 2010; Whitehouse et al., 2012) are negatively related to vocabulary at 2 years (Hollier et al., 2013) and are positively related to risk for language delay at 3 years (Whitehouse et al., 2012). Relatedly, Friederici et al. (2008) found that female newborns performed better at a phonological discrimination task than male newborns, and that newborns' testosterone levels were associated with language organization in the brain. However, the neurodevelopmental literature in this domain remains a bit mixed. For instance, in a recent literature review, Etchell et al. (2018) concluded that the literature provides inconclusive evidence for the association between brain structure and function and language outcomes, and for sex differences in brain development.

The above possibilities – caregiver behaviors, infant behaviors, and biological factors – are not mutually exclusive. Indeed, various social and biological factors may interact to shape the emergent gender difference in language development. For example, early gender differences in infant behavior (which could be biologically based) could evoke gender-differentiated caregiver behaviors, which then amplify any early gender differences as children age (Leaper, 2002). Similar bidirectional relations between biological and social processes have been hypothesized in other domains, such as infant motor development (Campbell & Eaton, 1999). More work is needed to uncover the processes at play here.

Cultural values and parental attitudes about gender

If differences in early language development are due to gender socialization, then parents' beliefs about gender roles likely influence the extent to which they parent girls and boys differently. When considering the cross-cultural variation in beliefs about gender, it may be especially informative to study gender differences in children's early language exposure and development cross-culturally and in more diverse populations than have been studied to date (e.g., Ferjan Ramírez, Hippe, Correa, Andert, and Baralt, 2022, who examined child-directed speech in Latinx families in the United States).

Even within a society, attitudes about gender vary between people and shift over time. Individual caregivers' attitudes about gender roles influence the way they engage in gender socialization behaviors with their children (Sutfin, Fulcher, Bowles, & Patterson, 2008). More broadly, the previous several decades have seen shifting attitudes about gender roles in the United States, with views becoming more egalitarian over time (Cotter, Hermsen, & Vanneman, 2011). This may align with results from Leaper et al. (1998)'s meta-analysis, which found that gender differences in early language input were decreasing over time. More research is needed to explore how families' and societies' views about traditional gender roles may affect children's language experiences by gender.

However, studies with large and diverse samples have found gender differences in children's early vocabularies (Eriksson et al., 2012; Frank et al., 2021) but no gender difference in children's early language input (e.g., Bergelson et al., 2019), in line with the results presented here. That said, most of this work has been conducted in Western countries, therefore limiting the broad generalizability of these results. Future studies with cross-cultural comparisons and more diverse samples could shed light on gender-related differences in children's language experiences across different populations.

Effect of child talk

While we did not find that language input varied by child gender overall, we did find that infants heard more language from others once they themselves began talking. This is in line with other research suggesting that caregivers may be more responsive to speech-like vocalizations than non-speech-like vocalizations (measured using LENA estimates, Warlaumont, Richards, Gilkerson, & Oller, 2014). Prior work has also suggested that in some contexts, caregivers adapt their speech to their child's language level (Cross, 1979; Huttenlocher et al., 2010; e.g., Snow, 1977). For example, recent work has demonstrated that parents are sensitive and responsive to children's word knowledge in structured in-lab interactions (e.g., George, Bulgarelli, Roe, & Weiss, 2019; Leung et al., 2021). Taken together, these studies provide evidence that caregivers are responsive to child language development. This responsiveness, in turn, can facilitate language development: previous studies suggest that contingent social feedback can encourage more developmentally mature vocalizations (e.g., more speech-like vocalizations, Warlaumont et al. (2014); or more canonical syllables, Goldstein, King, and West (2003); Goldstein and Schwade (2008)).

Using our longitudinal corpus of child input and productions that spans before and after the onset of talking, the present study extends these findings to children's naturalistic home input on a larger scale. We find that infants' language input changes once they begin talking, which could further benefit their growing language skills. This leads to an intriguing possibility: prior results suggesting that parents talk differently to girls and boys may simply reflect that parents speak more to their language-advanced children, who are more likely to be girls. Notably, the only case where we found a gender input effect was in an interaction with talk status. This points to a potentially complex interplay between children's language input, gender, and language skills, which future work should further explore.

Limitations

One limitation of the current study is that our sample was relatively homogeneous (primarily White and highly educated), and our results therefore may not generalize to other contexts or populations. This is a common limitation of studies on this topic; most prior studies have been conducted in monolingual English-speaking, middle-class families in the United States (see Table 1 for examples). More research with diverse samples is needed to explore how child gender may affect early language development in other cultural and linguistic contexts (see section "Cultural values and parental attitudes about gender" for discussion).

Additionally, while the present study analyzed infants' language input by gender, there are other demographic variables that may be associated with the quantity and/or quality of language input children receive. We note that two such variables, socioeconomic status (SES) and number of siblings, pose different limitations on the current work. Our sample was quite limited in its range of SES, and thus we were not in a good position to investigate SES effects on our outcomes. Our sample was less limited in the range of number of siblings that infants had, but given our relatively small N (44), splitting the data both by gender and by number of siblings was not statistically appropriate. Thus, we are unable to examine or control for these and other potential demographic variables in this study. More research is needed to investigate how these various factors may combine to influence infants' language input. In particular, work that samples either a much larger number of participants, or explicitly selects for variation and distribution of potential demographic variables of interest (which we did not), would be valuable.

Furthermore, while our unique dataset allowed us to analyze children's noun input and productions within a single sample, there may be other ways that children's input and productions vary that are not captured in our operationalizations. For example, previous research finds gender differences across a variety of language skills, including phonological awareness (e.g., Dodd, Holm, Hua, & Crosbie, 2003; Lundberg, Larsman, & Strid, 2012) and syntactic development (Bouchard, Trudeau, Sutton, Boudreault, & Deneault, 2009; e.g., Tse, Chan, Kwong, & Li, 2002). However, the current study only analyzed infants' productive vocabulary. This may limit our conclusions about language abilities broadly, as vocabulary may show a different pattern than other language skills.

Conclusion

Turning back to our research questions, we find that as expected, female infants had a larger vocabulary than males, and this difference grew across our 6–17 month age-range. However this difference was not readily explained by caretakers talking more to their infant girls than boys. Rather, the onset of talking (in concert with age, and in concert with gender) led to differences in the input: parents talked more to talkers.

While speech- and language-relevant clinical diagnoses are more prevalent in boys than in girls (Paul, 1993; Rescorla, 2011; Shriberg et al., 1999), the literature has been mixed regarding gender differences in early language within typically-developing infants and their ties to input. Our results from a unique corpus of child-centered home recordings taken over 6–17 months let us investigate differences in what children hear and say, within children, over time. Our findings confirm that girls have larger productive vocabularies, independent of language exposure. Children's own word production, rather than their gender alone, affected how much language input they received. This supports the broader notion that children actively influence their own language environments as they grow.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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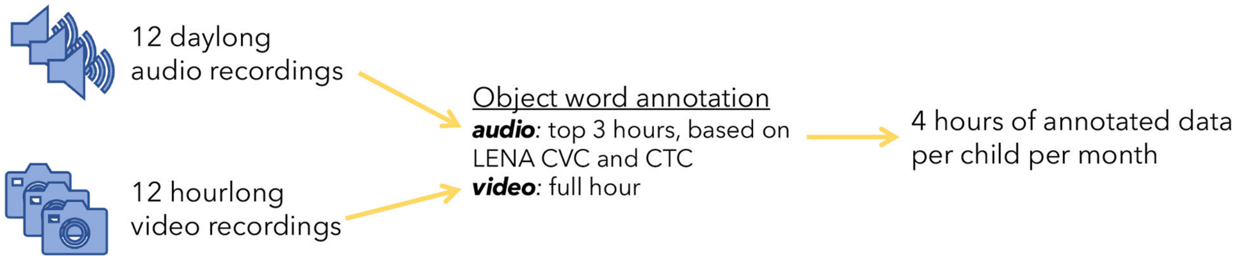

Figure 1.
Overview of data annotation pipeline.

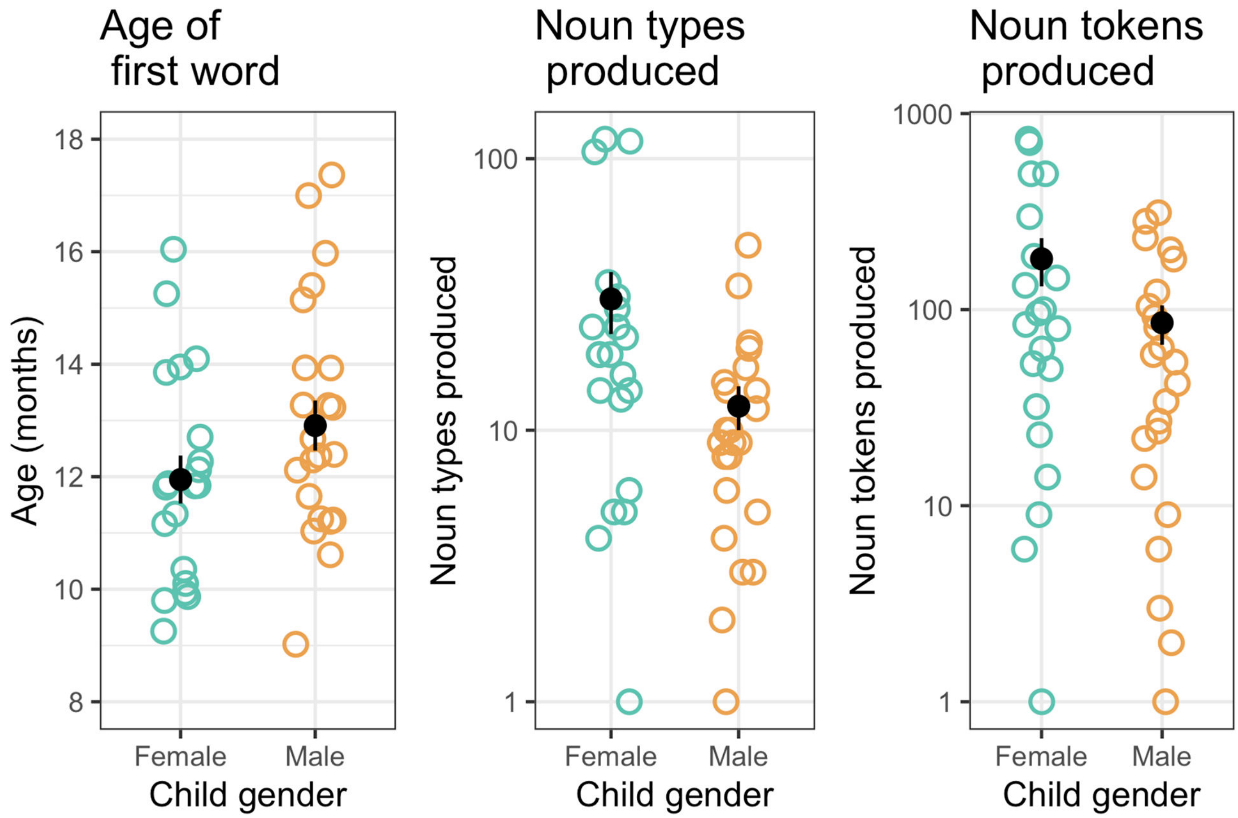

Figure 2.

Child noun productions by gender. Left panel shows age in months of first noun observed in audio or video recordings. Center and right panels show total noun types and tokens produced by children in our corpus (with y-axes log-transformed due to skewness). Statistical tests (which use log-transformed word counts) confirm a gender difference for types but not tokens or age of first word. Black points represent means with standard errors.

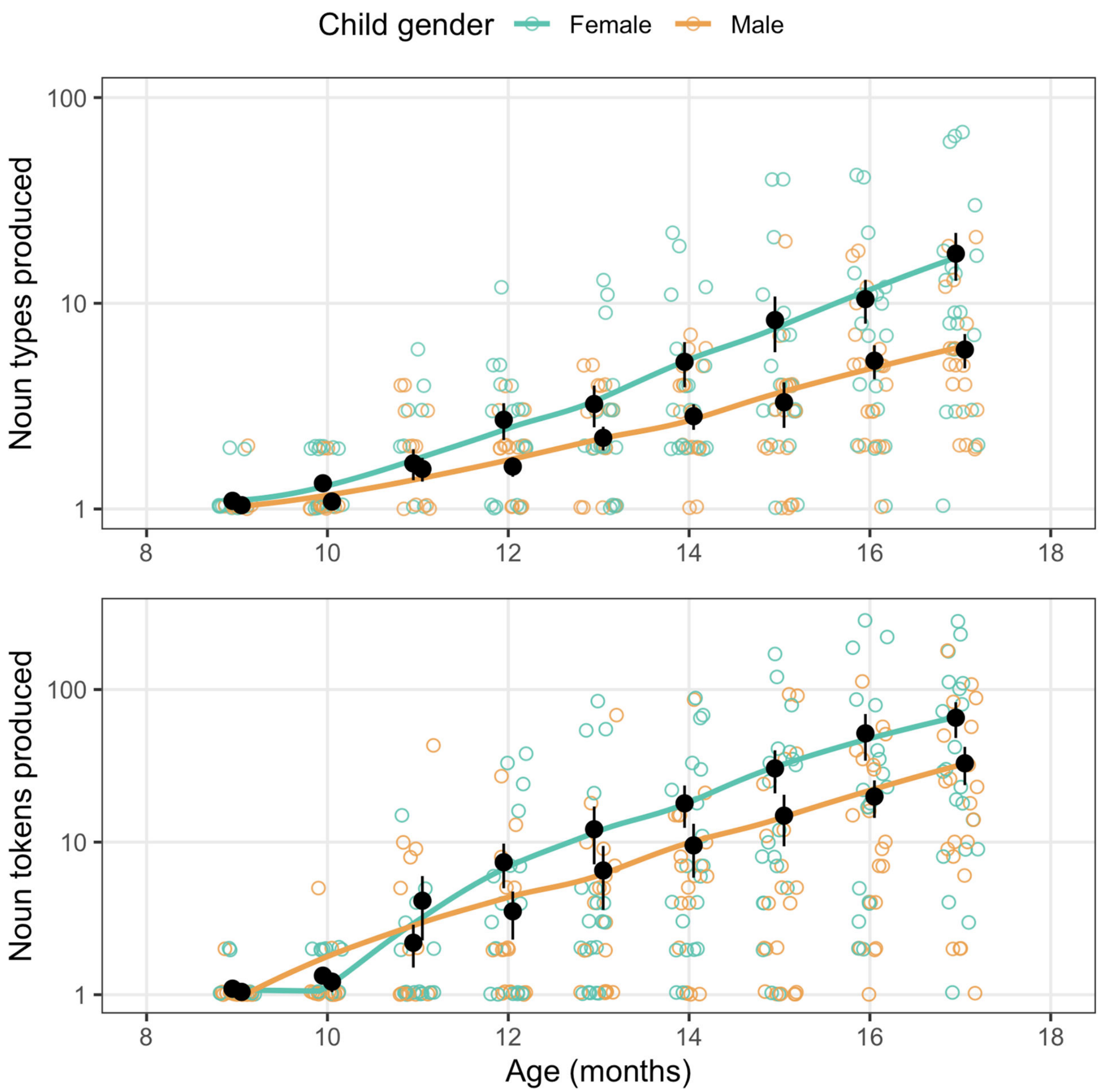

Figure 3.

Child productive noun vocabulary by gender from 9–17 months. Top panel represents noun types (i.e., unique nouns) and bottom panel represents noun tokens (i.e., total number of instances) produced by each infant. Black points represent means with standard errors. Statistical tests used log-transformed values and y-axis is log-transformed due to skewness.

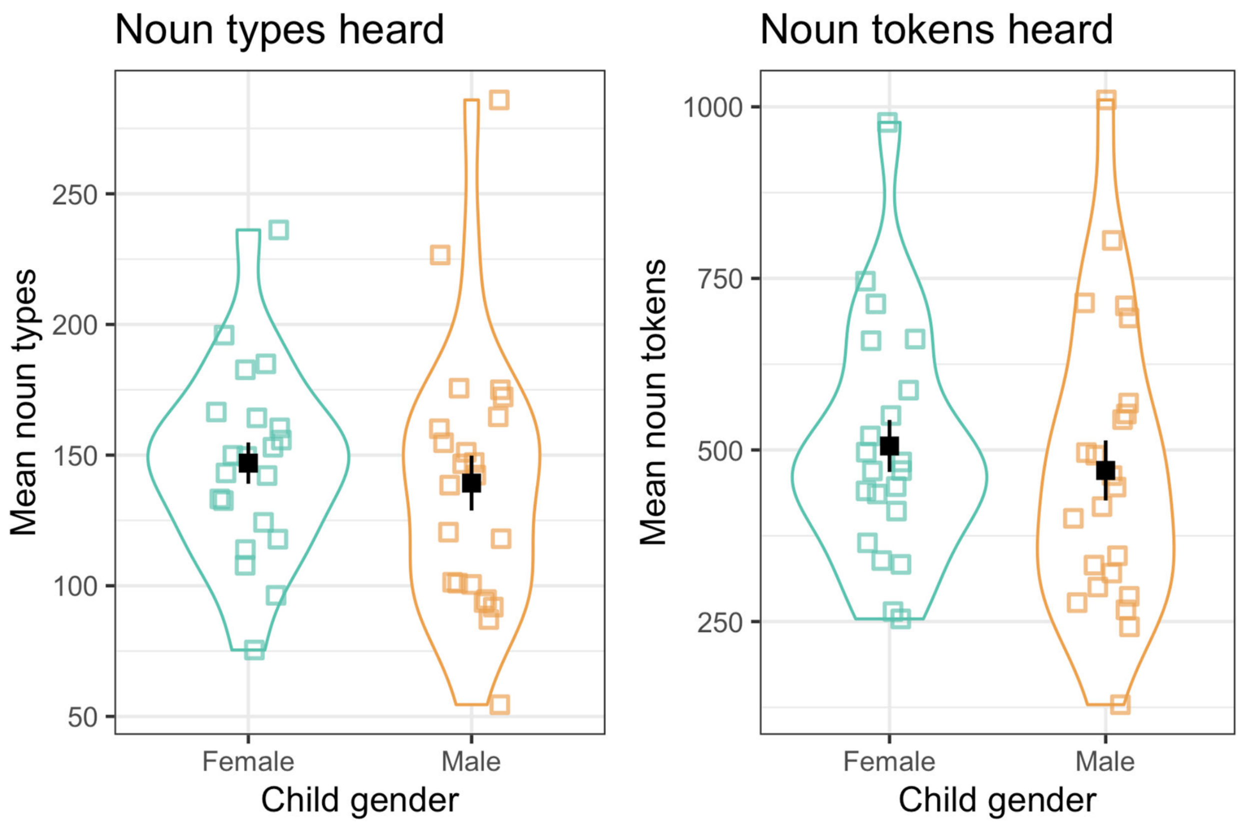

Figure 4.

Mean number of noun types (left panel) and tokens (right panel) heard by the infants. Each point represents one participant's mean word count across all months. Y-axis (and statistical tests) used square root-transformed values due to skewness. Black points represent means with standard errors. Neither types nor tokens in the input vary significantly by gender.

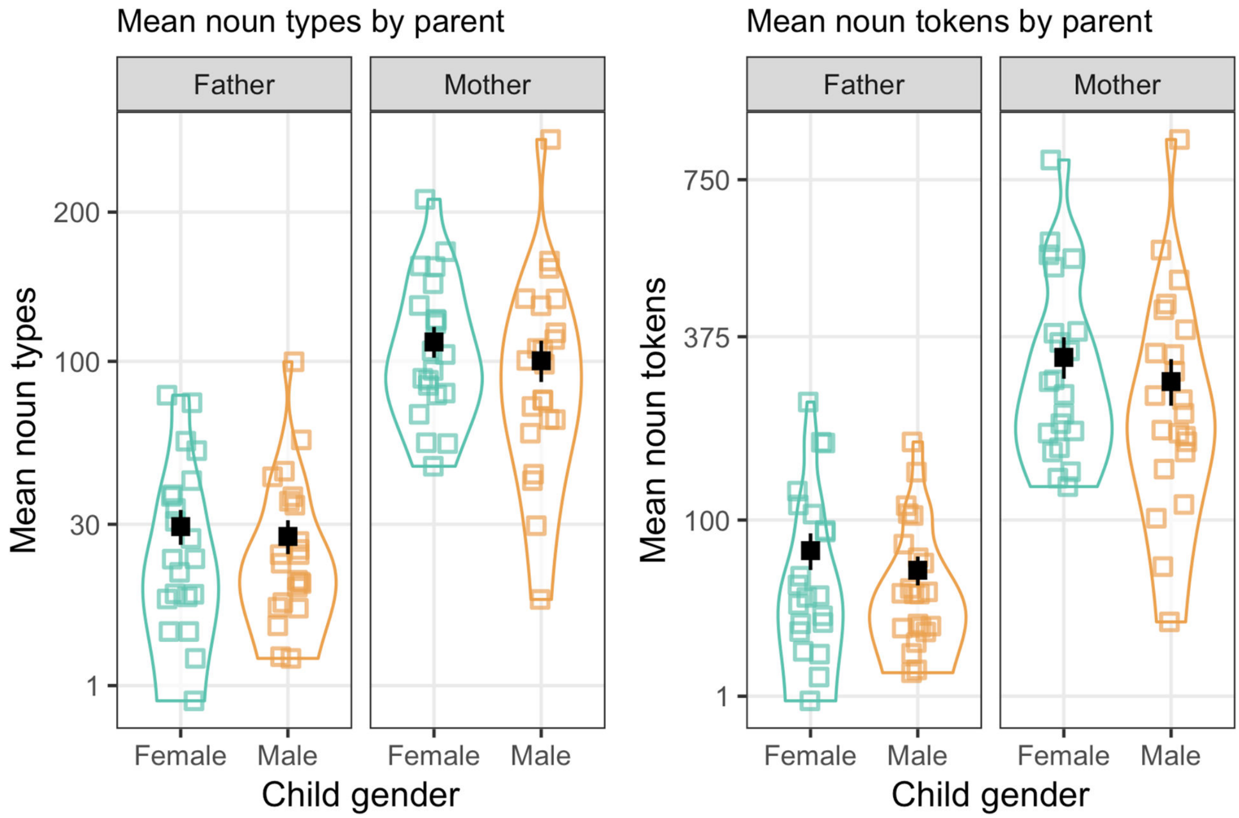

Figure 5.

Mean number of nouns (type and token) heard by the infants from each parent across the entire corpus. Statistical tests used square root-transformed values and y-axis is square root-transformed due to skewness. Black points represent means with standard errors. By both types and tokens, infants heard significantly more words from their mothers, with no effect of child gender.

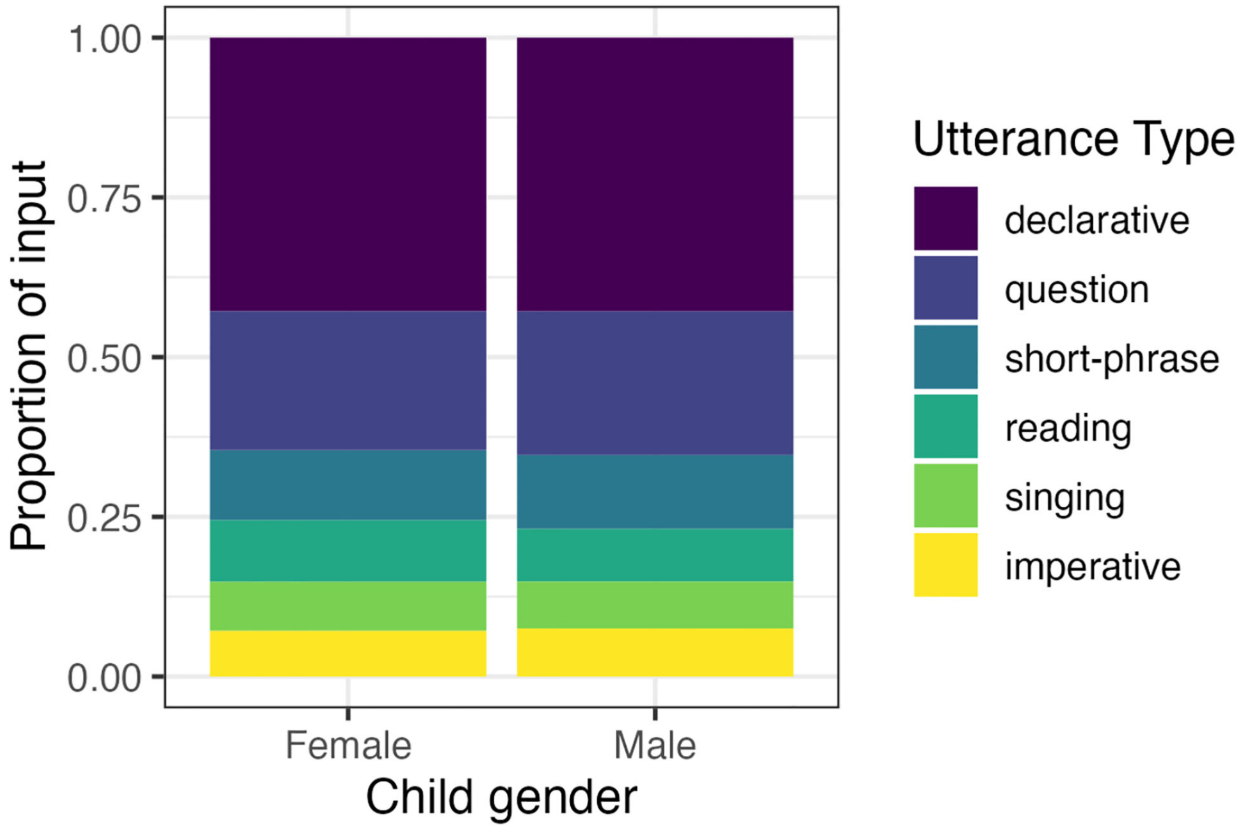

Figure 6.
Proportion of utterance types in the input by child gender.

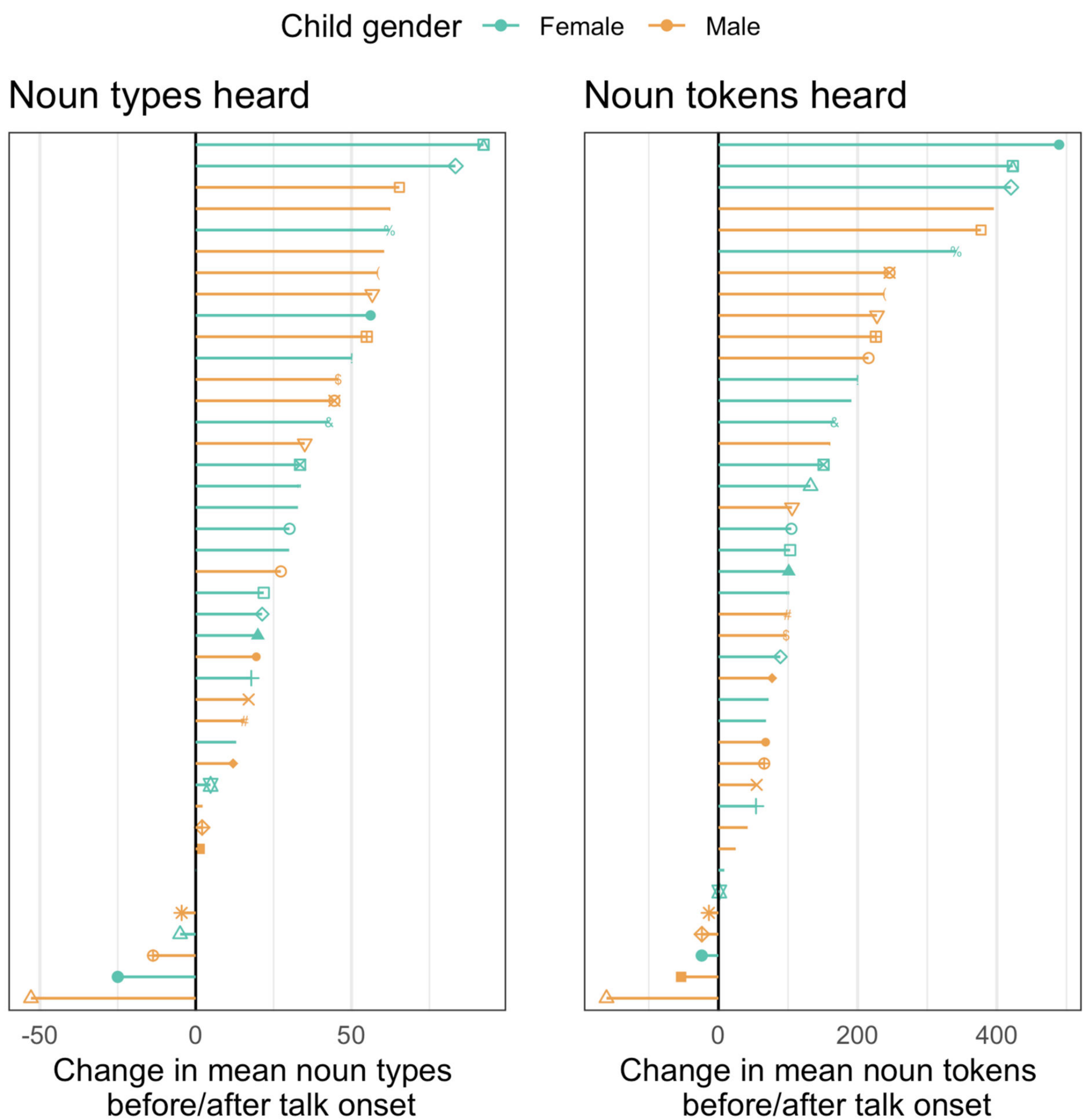

Figure 7.

Change in the average number of noun types (left panel) and tokens (right panel) heard by the infants before and after they start talking. Each line represents the difference in one child's mean input after they begin talking, compared to before. Thus, positive values represent an increase in input counts after the child begins talking. Each child is indicated by a unique symbol which is consistent across panels.

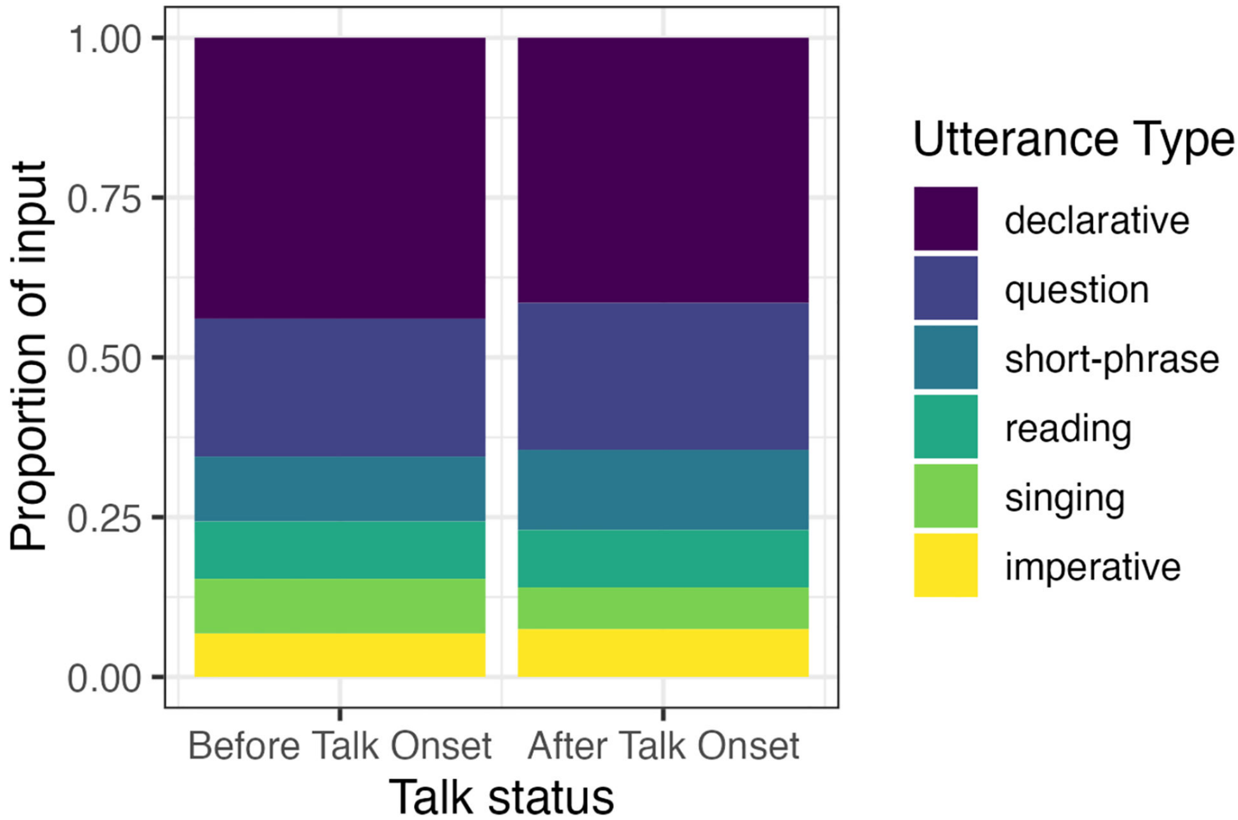

Figure 8.
Proportion of utterance types in the input by child talk status.

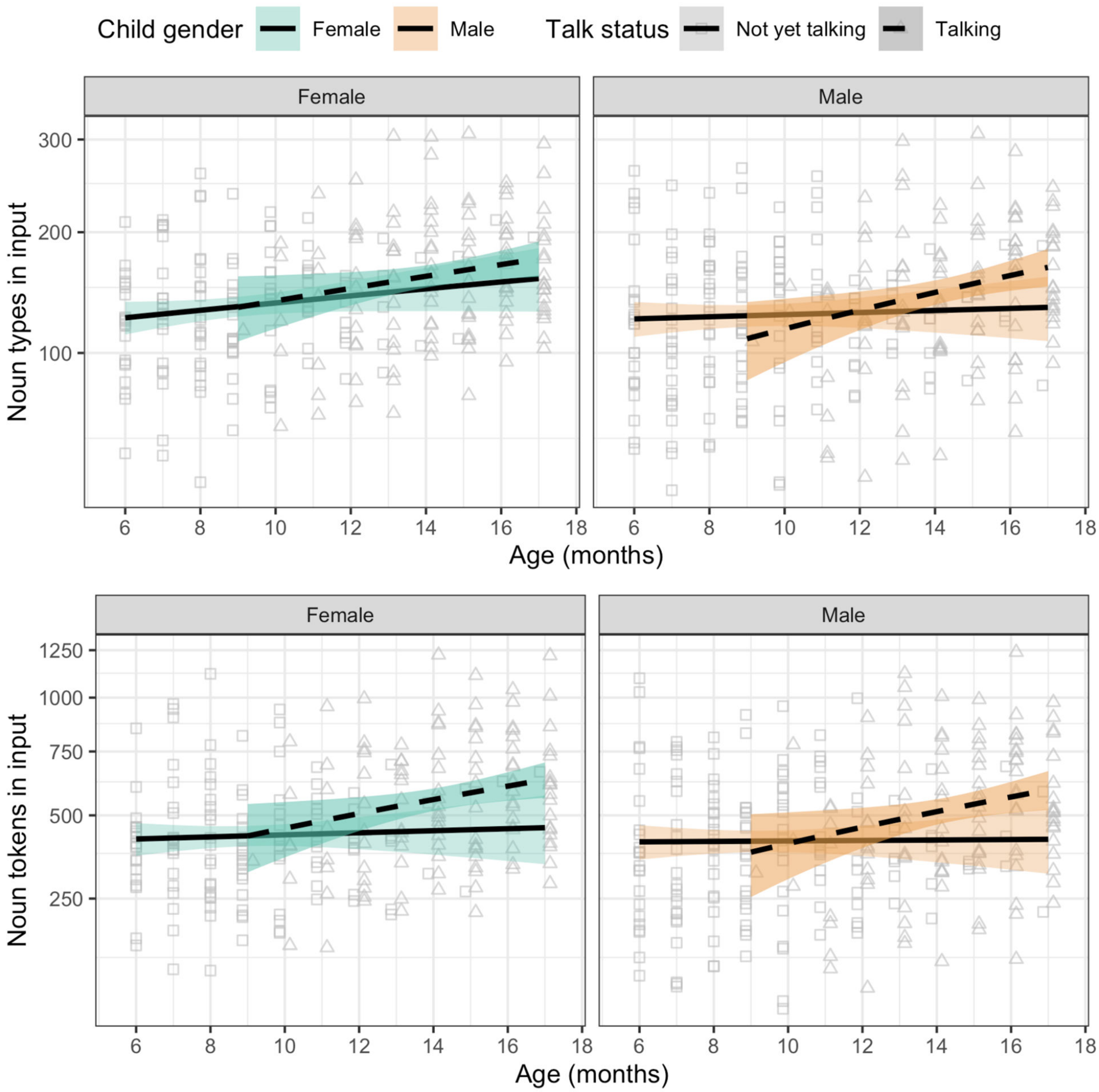

Figure 9.

Noun types (top panel) and tokens (bottom panel) in infants' input by age, talk status (i.e., whether or not the infant has said their first word), and gender. Each point represents one participant's word count each month. Y-axis (and regressions) used square root-transformed noun counts due to skewness. Squares and solid lines indicate infants not yet talking; triangles and dashed lines indicate infants who have begun talking. Shaded bands indicate 95% confidence intervals. For both types and tokens, we find a main effect of age, a talk status-by-gender interaction, and a talk status-by-age interaction, but not a 3-way interaction (see text for details).

Table 1.

Overview of current literature on gender differences in children’s language input. This sample of studies shows the inconsistencies in study methods and findings across the literature.

Paper	Age (mos)	Language	N	Caretaker	Language Sampling Method	Dependent Variable	Results
Johnson, et al., 2014	0–7	English	33	both parents concurrently	automated language analyses of 16-hr audio recordings	responsiveness	girls > boys
Cherry & Lewis, 1976	24	English	12	mothers	transcriptions of 15-min in-lab video recordings	utterances, questions, repetition, and utterance length	girls > boys
Clearfield & Nelson, 2006	6–14	English	36	mothers	transcriptions of 10-min in-lab video recordings	engagement, interpretations and conversation	girls > boys
Huttenlocher, et al., 1991	14–26	English	22	mothers	transcriptions of 3-to-5-hr audio and video recordings	tokens	girls = boys
Pinar, Ozturk, Ketrez, & Ozcaliskan, 2021	10–40	Turkish	97	various	transcriptions of 12-min in-lab video recordings	tokens, types, utterance length	girls = boys
Laflamme, 2002	15	French	85	both parents separately	coding of in-lab video recordings	vocalizations	girls = boys
Clearfield & Nelson, 2006	6–14	English	36	mothers	transcriptions of 10-min in-lab video recordings	comments, attentionals, and instructions	girls < boys
Weitzman, Birns, & Friend, 1985	30–42	English	40	mothers	transcription of at-home audio recordings (semi-structured tasks)	questions, teaching, action verbs	girls < boys
Laflamme, 2002	9	French	87	both parents separately	coding of in-lab video recordings	vocalizations	girls < boys

Table 2.

Summary of mixed effects regressions predicting child noun types and tokens. Outliers (>3SDs) were excluded from analysis. The interaction of child gender and age improves model fit for noun types, but not for noun token

	Noun types			Noun tokens		
	Model 1	**Model 2**	**Model 3**	**Model 4**	**Model 5**	**Model 6**
(Intercept)	**−0.91 (0.07) *** **	**−0.83 (0.08) *** **	**−1.09 (0.10) *** **	**−1.46 (0.12) *** **	**−1.37 (0.13) *** **	**−1.67 (0.17) *** **
Age in mos.	**0.10 (0.00) *** **	**0.10 (0.00) *** **	**0.12 (0.01) *** **	**0.15 (0.01) *** **	**0.15 (0.01) *** **	**0.18 (0.01) *** **
Gender		**−0.15 (0.07) * **	**0.35 (0.14) ** **		−0.17 (0.11)	0.40 (0.23)
Age*gender			**−0.04 (0.01) *** **			**−0.04 (0.02) ** **
AIC	98.94	99.68	91.08	516.95	519.26	519.97
BIC	114.86	119.58	114.97	532.87	539.17	543.86
Log Likelihood	−45.47	−44.84	−39.54	−254.47	−254.63	−253.99
Num. obs.	396	396	396	396	396	396
Num. groups: subj	44	44	44	44	44	44
Var: subj (Intercept)	0.05	0.05	0.05	0.12	0.11	0.11
Var: Residual	0.06	0.06	0.05	0.17	0.17	0.16

Table 3.

Summary of mixed effects regressions predicting noun types and tokens in infants' input by parent and child gender. Adding the interaction term (i.e., Models 2 and 4) does not improve model fit.

	Model 1	**Model 2**	**Model 3**	**Model 4**
(Intercept)	**5.03 (0.43) *** **	**4.89 (0.50) *** **	**7.55 (0.84) *** **	**7.31 (0.97) *** **
Parent (mom)	**5.17 (0.49) *** **	**5.46 (0.70) *** **	**9.91 (0.96) *** **	**10.40 (1.38) *** **
Child gender (M)	−0.43 (0.49)	−0.14 (0.69)	−1.07 (0.96)	−0.60 (1.36)
Parent*child gender		−0.58 (0.98)		−0.95 (1.93)
R^2	0.58	0.58	0.57	0.57
Adj. R^2	0.57	0.56	0.56	0.55
Num. obs.	86	86	86	86

Table 4.

Summary of mixed effects regressions testing for interactions between age, gender, and talk status on infants' noun input (types and tokens).

	Noun types		**Noun tokens**	
(Intercept)	**10.53 (0.60) *****	**10.49 (0.64) *****	**19.09 (1.36) *****	**19.47 (1.46) *****
Age in mos.	0.09 (0.05)	0.10 (0.06)	0.13 (0.12)	0.08 (0.13)
Talk status	−1.12 (0.77)	−0.99 (1.05)	−3.38 (1.75)	−4.57 (2.41)
Child gender	−1.15 (0.76)	−1.08 (0.86)	−2.24 (1.74)	−2.89 (1.97)
Age*Talk status	**0.12 (0.06) ***	0.11 (0.08)	**0.41 (0.13) ****	**0.51 (0.19) ****
Talk status*gender(M)	−**0.89 (0.45) ***	−1.15 (1.50)	−**2.15 (1.03) ***	0.20 (3.42)
Age*gender(M)	0.10 (0.06)	0.09 (0.08)	0.20 (0.14)	0.27 (0.17)
Age*talk*gender(M)		0.02 (0.12)		−0.19 (0.27)
Log Likelihood	−998.72	−999.93	−1417.29	−1417.44
Num. obs.	521	521	520	520
Num. groups: subj	44	44	44	44
Var: subj (Intercept)	2.94	2.94	15.61	15.64
Var: Residual	2.09	2.09	10.73	10.74