Child language experience in a Tseltal Mayan village

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Abstract

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Keywords: Child-directed speech, Linguistic input, Non-WEIRD, Vocal maturity, Turn taking

Word count: X

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Introduction

A great deal of work in developmental language science revolves around one central question: What linguistic evidence (i.e., what types and how much) is needed to support first language acquisition? In pursuing this topic, many researchers have fixed their sights on child-directed speech (CDS), showing that it is linguistically distinctive (REFS)[**TASK 00: Add missing references**], interactionally rich (REFS), preferred by infants (REFS), and—perhaps most importantly—facilitates word learning (REFS). By all appearances, CDS is an essential component for acquiring a first language. Yet ethnographic reports from a number of traditional, non-Western communities suggest that children easily acquire their community's language(s) with little or no CDS (REFS). If so, CDS may not be essential for learning language; just useful for facilitating certain aspects of language development. In this paper we investigate the language environment and early development of 10 Tseltal Mayan children growing up in a community where past research has suggested that caregivers use little CDS with infants and young children (REFS Brown).

Child-directed speech

The amount of CDS children hear influences their language development, particularly their vocabulary (REFS). For example, [**TASK 01: Add examples of input-vocab link**]. CDS has also been linked to young children's speed of lexical retrieval (REFS Weisleder; LuCiD) and syntactic development (REFS Huttenlocher). [**TASK 02: Read Huttenlocher and add details here**]. The conclusion drawn from much of this work is that CDS is an ideal register for learning words—especially concrete nouns and verbs—because it is tailored to maximize a child's moment-to-moment interest and understanding (REFS). Indeed, even outside of first-person interaction, infants and young children prefer listening to CDS over adult-directed speech (REFS ManyBabies, etc.), suggesting that CDS is useful in catching, maintaining, and focusing children's attention.

There are, however, a few significant caveats to the body of work relating CDS quantity to language development.

First, while there is overwhelming evidence linking CDS quantity to vocabulary size, links to grammatical development are more scant (REFS: Huttenlocher; Frank et al.). While the advantage of CDS for referential word learning is clear, it is less obvious how CDS facilitates syntactic learning. [**TASK 03: Add argument from Yurovsky paper + refrences therein**] On the other hand, there is a wealth of evidence that both children and adults' syntactic knowledge is highly lexically specified (REFS), and that, crosslinguistically, children's vocabulary size is one of the most robust predictors of their early syntactic development (REFS). In short, what is good for the lexicon may also be good for syntax. For now, however, the link between CDS and other aspects of grammatical development still needs to be more thoroughly tested.

A second caveat is that most work on CDS quantity uses summary measures that average over the ebb and flow of interaction (e.g., proportion CDS). In both child and adult interactions, verbal behaviors are highly structured: while some occur at fairly regular intervals ("periodic"), others occur in shorter, more intense bouts separated by long periods of inactivity ("bursty" REFS Abney 2018 bursts and lulls, see also fusaroli et al. 2014 synergy). For example, Abney and colleagues (2016 REFS) found that, across multiple time scales of daylong recordings, both infants' and adults' vocal behavior was clustered. Focusing on lexical development, Blasi and colleagues (REFS in prep) also found that nouns and verbs were used burstily in child-proximal speech across all six of the languages in their typologically diverse sample. Infrequent words were somewhat more bursty overall, leading them to propose that burstiness may play a key and universal role in acquiring otherwise-rare linguistic units (see also REFS in prep from ICIS).[1] Experiment-based work also shows that two-year-olds learn novel words better from a massed presentation of object

[1]But see Drew and Bergelson (REFS in preparation), who find that the highest-frequency nouns used in CDS and children's own speech were relatively more bursty than other nouns.

labels versus a distributed presentation (Schwab and Lew-Williams (2016) REFS; but see REFS Ambridge et al., 2006; Childers and Tomasello, 2002). Structured temporal characteristics in children's language experience imply new roles for attention and memory in language development. By that token, we should begin to investigate the link between CDS and linguistic development with more nuanced measures of how CDS is distributed.

Finally, prior work has typically focused on Western (primarily North American) populations, limiting our ability to generalize these effects to children acquiring language worldwide (REFS: WEIRD; Lieven, 1994). While we do gain valuable insight by looking at *within-population* variation (e.g., REFS), we can more effectively find places where our assumptions break down by studying *new* populations. Linguistic anthropologists working in non-Western communities have long reported that caregiver interaction styles vary immensely from place to place, with some caregivers using little or no CDS to young children (REFS Gaskins, 2006). Children in these communities reportedly acquire language with "typical"-looking benchmarks. For example, they start pointing (REFS Liszkowski et al., 2012; but see Salomo & Liszkowski, 2013) and talking (REFS Rogoff et al., 2003?; Brown??) around the same time we would expect for Western middle-class infants. These findings have had little impact on mainstream theories of word learning and language acquisition, partly due to a lack of directly comparable measures (Brown, 2014). If, however, these children indeed acquire language without delay despite little or no CDS, we must reconsider what kind of linguistic evidence is necessary for children to learn language.

Language development in non-WEIRD communities

To our knowledge, only a handful of researchers have used methods from developmental psycholinguistics to describe the language environments and linguistic development of children growing up in traditional, non-Western communities. We briefly highlight two recent efforts along these lines, but see Mastin and Vogt (REFS 2016) and Cristia et al. (2017) for more examples.

Scaff, Cristia, and colleagues (REFS 2017; in preparation) have used a number of methods to estimate how much speech children hear in a Tsimane forager-horticulturalist population in the Bolivian lowlands. Their daylong recordings show that Tsimane children between 0;6 and 6;0 hear ~5 minutes of CDS per hour, regardless of their age (but see Cristia et al., 2017). For comparison, children from North American homes between ages 0;3 and 3;0 are estimated to hear ~11 minutes of CDS per hour in daylong recordings (REFS: Bergelson, Casillas, et al., see also REFS the newer Tamis-LeMonda paper; maybe give estimates w/ age ranges for each??). Tsimane children also hear ~10 minutes of other-directed speech per hour (e.g., talk between adults) compared to the ~7 minutes per hour heard by North American children (REFS Bergelson, Casillas, et al.). This difference may be attributable to the fact that the Tsimane live in extended family clusters of 3–4 households, so speakers are typically in close proximity to 5–8 other people (REFS Cristia et al., 2017).

Laura Shneidman and colleagues (REFS; 2010; 2012) analyzed speech from 1-hour at-home video recordings of children between ages 1;0 and 3;0 in two communities: Yucatec Mayan (Southern Mexico) and North American (a major U.S. city). Their analyses yielded four main findings: compared to the American children, (a) the Yucatec children heard many fewer utterances per hour, (b) a much smaller proportion of the utterances they heard were *child-directed*, (c) the proportion of utterances that were child-directed increased dramatically with age, matching U.S. children's by 3;0 months, and (d) most of the added CDS came from other children (e.g., older siblings and cousins). They also demonstrated that the lexical diversity of the CDS they hear at 24 months—particularly from adult speakers—predicted children's vocabulary knowledge at 35 months.

These groundbreaking studies establish a number of important findings: First, children in each of these communities appear able to acquire their languages with relatively little CDS. Second, CDS might become more frequent as children get older, though this could largely be due to speech from other children. Finally, despite these differences, CDS from adults may still be the most robust predictor of vocabulary growth.

The current study

We examine the early language experience of 10 Tseltal Mayan children under age 3;0. Prior ethnographic work suggests that Tseltal caregivers do not frequently speak directly to their children until the children themselves begin speaking (REFS: Brown??). Nonetheless, Tseltal children develop language with no apparent delays. Tseltal Mayan language and culture has much in common with the Yucatec Mayan communities Shneidman reports on (REFS: 2010 + add other stuff that's not nec lg), allowing us to compare differences in child language environments between the two sites more directly than before.\footnote{For a review of comparative work on language socialization in Mayan cultures, see Pye (2017).) We provide more details on this community and dataset in the Methods section.

Similar to previous work, we estimated how much speech children overheard, how much was directed to them, and how those quantities changed with age. To this foundation we added new sampling techniques for investigating variability in children's speech environments within daylong recordings. We also analyzed children's early vocal productions, examining both the overall developmental trajectory of their vocal maturity and how their vocalizations are influenced by CDS.

Based on prior work, we predicted that Tseltal Mayan children hear little CDS, that the amount of CDS they hear increases with age, that most CDS comes from other children, and that, despite this, Tseltal Mayan children reach speech production benchmarks on par with Western children. We additionally predicted that children's language environments would be bursty—that brief, high-intensity interactions would be sparsely distributed throughout the day, accounting for the majority of children's daily CDS—and that children's responsiveness and vocal maturity would be maximized during these moments of high-intensity interaction.

Methods

Community

The children in our dataset (REFS: Casillas HomeBank) come from a small-scale, subsistence farming community in the highlands of Chiapas in Southern Mexico. The vast majority of children grow up speaking Tseltal monolingually at home. Primary school is conducted in Tseltal, but secondary and further education is primarily conducted in Spanish. Nuclear families are often large (5+ children) and live in patrilineal clusters. Nearly all families grow staple crops such as corn and beans, but also bananas, chilies, squash, coffee, and more. Household and farming work is divided among men, women, and older children. Women do much of the daily cleaning and food preparation, but also frequently work in the garden, haul water and firewood, and do other physical labor. A few community members—both men and women—earn incomes as teachers and shopkeepers but are still expected to regularly contribute to their family's household work.

More than forty years of ethnographic work by the second author has reported that Tseltal children's language environments are non-child-centered and non-object-centered (REFS). During their waking hours, Tseltal infants are typically tied to their mother's back while she goes about her work for the day. Infants receive very little direct speech until they themselves begin to initiate interactions, usually as they approach their first birthdays. Even then, interactional exchanges are often brief or non-verbal (e.g., object exchange routines) and take place within a multi-participant context (Brown 2011; 2014). Rarely is attention given to words and their meanings, even when objects are central to the activity. Instead, interactions tend to focus on appropriate actions and responses, and young children are socialized to attend to the interactions taking place around them (REFS see also Rogoff and de Leon).

Young children are often cared for by other family members, especially older siblings. Even when not on their mother's back, infants are rarely put on the ground, so they can't usually pick up the objects around them until they are old enough to walk. Toys are scarce and books are vanishingly rare, so the objects children do get their hands on tend to be natural or household objects (e.g., rocks, sticks, spoons, baskets, etc.). By age five, most children are competent speakers who engage daily in chores and caregiving of their younger siblings. The Tseltal approach to caregiving is similar to that described for other Mayan communities (e.g., REFS Rogoff, Gaskins, de Leon, Shneidman).

Corpus

The current data come from the Casillas HomeBank Corpus (REFS HomeBank), which includes daylong recordings and other developmental language data from more than 100 children under 4;0 across two indigenous, non-WEIRD communities: the Tseltal Mayan community described here and a Papua New Guinean community described elsewhere (REFS).

[TASK 06: Check these demographic data again] The Tseltal data, primarily collected in 2015, include recordings from 55 children born to 43 mothers. The families in our dataset typically only had 2–3 children (median = 2; range = 1–9), due to the fact that the participating families come from a young subsample of the community (mothers: mean = 26.9 years; median = 25.9; range = 16.6–43.8 and fathers: mean = 30.5; median = 27.6; range = 17.7—52.9). On average, mothers were 20.1 years old when they had their first child (median = 19; range = 12–27), with a following inter-child interval of 3.04 years (median = 2.8; range = 1–8.5).[2]. As a result, 26% of the participating families had two children under 4;0.

Extended households, defined in our dataset as the group sharing a kitchen or other primary living space, ranged between between 3 and 15 people (mean = NN; median = NN). Although 30.9% of the target children are first-born, they were rarely the only child in their extended household. Caregiver education is one (imperfect) measure of contact with Western culture. Most mothers had finished primary school, with many also having completed

[2] These estimates do not include miscarriages and/or children who passed away.

secondary school (range = no schooling–university). Most fathers had finished secondary school, with many having also completed preparatory school (range = no schooling–university). Owing in large part to patrilineal (i.e., father to son) land inheritance, 93% of the fathers grew up in the village where the recordings took place, while only 53% of the mothers did.

Recordings. Methods for estimating the quantity of speech that children hear have advanced significantly in the past two decades, with long-format at-home audio recordings quickly becoming the new standard (e.g., with the LENA® system; REFS). These recordings capture a wider range of the linguistic patterns children hear as they participate in different activities with different speakers over the course of their day. In longer, more naturalistic recordings, caregivers also tend to use less CDS (REFS Tamis-LeMonda). The result is greater confidence that the estimated CDS characteristics are representative of what the child typically hears at home.

We used a novel combination of a lightweight stereo audio recorder (Olympus® WS-832) and wearable photo camera (Narrative Clip 1®) fitted with a fish-eye lens, to track children's movements and interactions over the course of a 9–11-hour period in which the experimenter was not present. Each recording was made during a single day at home in which the recorder and/or camera was attached to the child. Ambulatory children wore both devices on an elastic vest. Non-ambulatory children wore the recorder in a onesie while their primary caregiver wore the camera on an elastic vest *Figure 1 [TASK 07: Make figure]*. The camera was set to take photos at 30-second intervals and was synchronized to the audio in post-processing to create video of the child's daylong recording.[3]

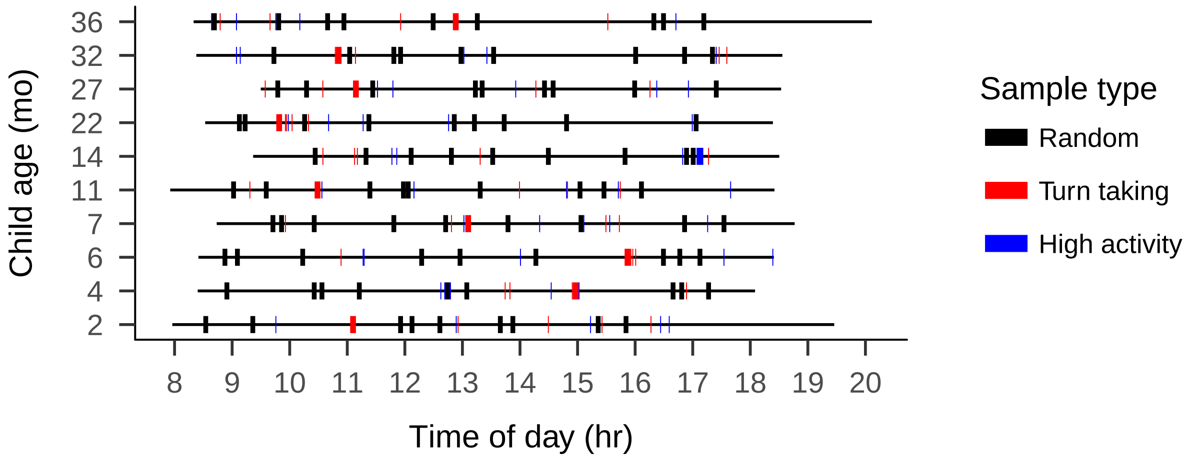
Data selection and annotation

We annotated video clips from 10 of the 55 children's recordings. We chose these 10 recordings to maximize variance in three demographic variables: child age (0–3;0), child sex,

[3] Documentation for recording set-up and scripts for post-processing are available at *[TASK 08: Link to relevant docs]*

and maternal education. The sample is summarized in *Table 1 [TASK 09: Make table]*. We then selected one hour's worth of non-overlapping clips from each recording in the following order: nine randomly selected 5-minute clips, five 1-minute clips manually selected as the top "turn-taking" minutes of the recording, five 1-minute clips manually selected as the top "vocal activity" minutes of the recording, and one, manually selected 5-minute extension of the best 1-minute sample *FIGURE ?? [TASK 10: Add figure of recording times with samples highlighted for the 10 recs]*. We created these different subsamples of each day to measure properties of (a) children's *average* language environments (random samples) and (b) their *most input-dense* language environments (turn-taking samples). The third sample (high-activity) gave us insight into children's productive speech abilities.

The turn-taking and high-activity clips were chosen by two trained annotators (the first author and a student assistant) who listened to each recording in its entirety at 1–2x speed while actively taking notes about potentially useful clips. Afterwards, the first author reviewed the list of candidate clips, listened again to each one (at 1x speed, multiple repetitions), and chose the best five 1-minute samples for each of the two types of activity. Good turn-taking activity was defined as at closely timed sequences of contingent vocalization between the target child and at least one other person (i.e., frequent vocalization exchanges). The "best" turn-taking clips were chosen because they had the most and most clear turn-switching activity between the target child and the other speaker(s). Good vocal activity clips were defined as clips in which the target child produced the most and most diverse spontaneous (i.e., not imitative) vocalizations. The "best" vocal activity clips were chosen for representing the most linguistically mature and/or diverse vocalizations made by the child over the day. All else being equal, candidate clips were prioritized when they contained less background noise or featured speakers and speech that were not otherwise frequently represented (e.g., CDS from older males). The best turn-taking clips and vocal activity clips often overlapped; turn-taking clips were selected from the list of candidates first, and then vocal-activity clips were chosen from the remainder.



Each video clip was transcribed and annotated in ELAN (REFS) using the ACLEW Annotation Scheme (REFS) by the first author and a native speaker of Tseltal who lives in the community and knows most of the recorded families personally. At the time of writing, NN% *[TASK XX: Fill in before submitting]* of the clips have been reviewed by a second native Tseltal speaker. The annotations include the transcription of (nearly) all hearable utterances in Tseltal, a loose translation of each utterance into Spanish, vocal maturity measures of each target child utterance (non-linguistic vocalizations/non-canonical babbling/non-word canonical babbling/single words/multiple words), and addressee annotations for all non-target-child utterances (target-child-directed/other-child-directed/adult-directed/adult-and-child-directed/animal-directed/other-speaker-type-directed).[4]

Why vocal maturity?. *[TASK 12: Missing paragraph!!]*

Data analysis

We exported each ELAN file as tab-separated values and then the annotations into R version 3.5.0 (2018-04-23) for analysis (plots: ggplot2; analyses: lme4 and betareg *[TASK 13: Fix references to packages and their citations]*). We then calculated a number of summary variables to characterize children's language environments and linguistic development

[4]Full documentation, including training materials, for the ACLEW Annotation Scheme can be found at *[TASK 11: Add OSF link]*.

including: the rate of all overheard speech ("XDS") and all speech directed to the target child ("TCDS") in both minutes per hour and utterances per hour, the proportion of speech in TCDS and coming from adult vs. child speakers, the rate of target-child-to-other and other-to-target-child turn transitions, the rate of vocalization produced by the target child, and the average maturity of children's vocalizations. Using language environment measures from the turn-taking sample, we then also estimated the number of intensive interaction minutes each child experienced over the day.

Results

Speech quantity

How much speech do Tseltal children hear overall and what proportion of that speech is directed to them? For maximum comparability with prior work we first limit direct comparisons to the randomly sampled Tseltal clips. During randomly sampled clips, Tseltal children heard an average of 24.68 minutes of speech per hour (median = 20.12; range = 8.23–48.60), of which an average of 3.63 minutes were directed toward the target child (median = 4.08; range = 0.83–6.55). Consequently, the mean proportion of speech directed to children was 0.29 (median = 0.28; range = 0.05–0.77). By-child estimates of the overheard speech (other-directed speech; "ODS") rate, target-child-directed speech ("TCDS") rate, proportion TCDS (TCDS/(TCDS+ODS)), and TCDS rate from adult vs. child caregivers are shown in figure 1. To these figures we have added estimates from prior work with other communities.[5].

We modeled these measures for the nine clips from each child using mixed-effects regression using the glmmTMB package in R (REF). Notably, gaussian linear regression is not appropriate for any of our measures . The rate-based dependent variables (ODS min/hr

[5]The Yucatec Mayan data from Shneidman and colleagues was originally reported in utterances per hour. We convert their estimates to minutes per hour using the median utterance duration in our dataset for all non-target child speakers (1029ms)

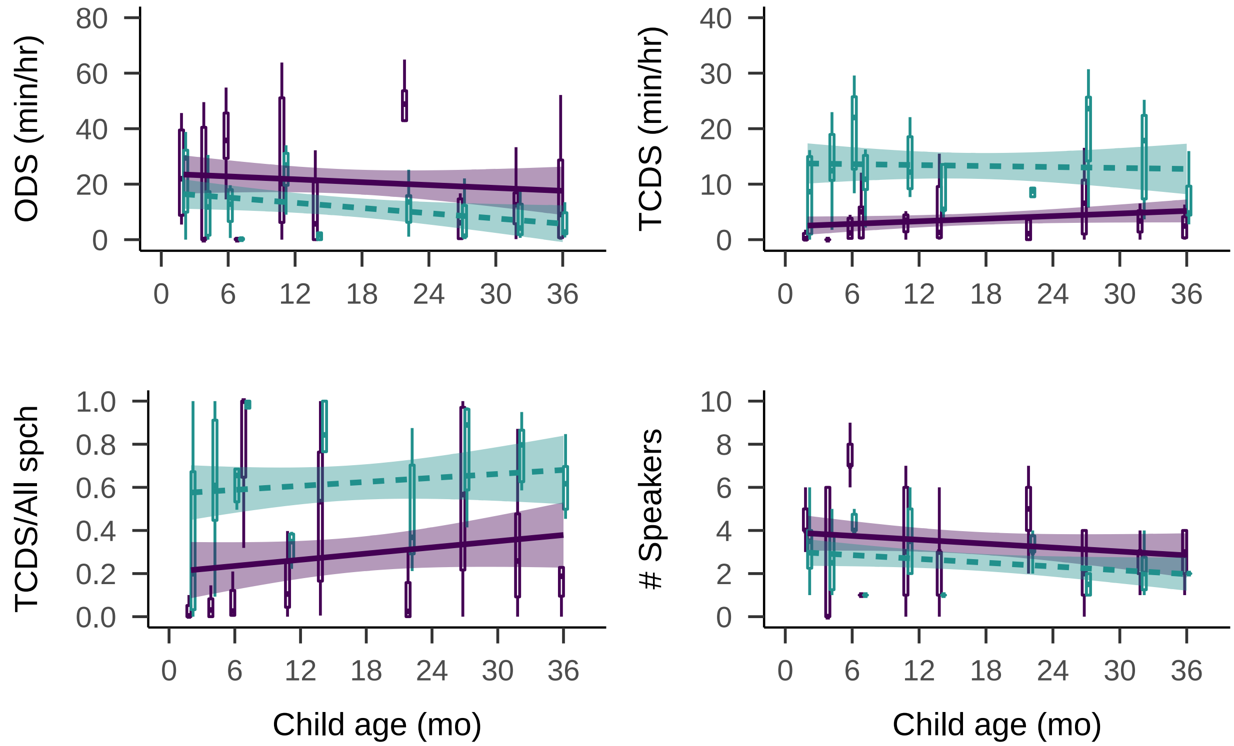


Figure 1. By-child estimates of minutes per hour of overheard speech (upper left), target-child-directed speech (upper right), proportion of speech that is directed to the target child (lower left), and number of speakers present (lower right). Data are shown for the random (purple; solid) and turn taking (green; dashed) samples. Bands on the solid linear trends show 95% CIs.

and TCDS min/hr) are continuous with a zero-inflated positive distribution, the proportion TCDS variable (TCDS/(TCDS+ODS)) is doubly-bounded, and the number of speakers is count data (i.e., non-continuous).

To address this issue for the rate variables (ODS and TDS min/hr), we rounded each rate estimate down to nearest minute per hour to treat it as count data and then employed zero-inflated negative binomial regression (ZINB). ZINB regressions model the dependent variable in two ways: (1) a binomial ("zero-inflation") model that evaluates the likelihood that a datapoint is zero or non-zero and (2) a negative binomial ("conditional") model of all the non-zero datapoints (REF). For proportion TCDS we used beta regression, which is suited to making predictions on doubly-bounded data (for more details see Smithson REFS).

Our primary predictors were as follows: child age, household size, and number of non-target-child speakers present in that clip (all centered and standardized), plus maternal education (pre-secondary vs. secondary-plus)[6], and squared time of day at the start of the clip (in decimal hours; centered on noon and standardized). We used squared time of day to model the cycle of activity at home: mealtimes in the mornings and evenings should be more similar to each other than the afternoon because of dispersal for chores. To this we also added two-way interactions between child age and maternal education, number of speakers, household size, and time of day. Finally, we included a random effect of child, with random slopes of time of day, unless doing so resulted in model non-convergence. Finally, for the zero-inflation models of zero-vs-nonzero ODS and TDS rate, we included household size, number of speakers present, and time of day, with interactions between time of day and household size and time of day and number of speakers present. The zero-inflation models used the same random effects structure as their complementary conditional models. We often had to reduce the fixed effects structure in the zero-inflation model to achieve convergence, as detailed below.

The quantity of other-directed speech (ODS) was primarily affected by the number of speakers present (MODEL-REF): more speakers was associated with more overheard speech. ODS was also significantly affected by time of day, being more frequent in the mornings and evenings than around midday (MODEL-REF). ODS was also more frequent in large households for older children compared to younger children (MODEL-REF). There was no significant effect of child age overall, and no effect involving maternal education. The zero-inflation model of ODS included fixed effects of household size, time of day, and their interaction, but none of these predictors were significant.

The quantity of target-directed speech (TCDS) was primarily affected by factors relating to the child's age. Older children heard more TCDS (MODEL-REF) than younger

[6]Spanish-only education begins in secondary school.

children in general, particularly when many other speakers were present (MODEL-REF). This also meant that, compared to younger children, older children showed a much stronger effect of time of day: younger children tended to hear a stable quantity of TCDS throughout the day while older children heard much more TCDS in the mornings and evenings compared to midday (MODEL-REF). The zero-inflation model of TCDS also showed significant effects of house size, time of day, and the interaction of time of day and number of speakers; TCDS is more likely to be present in smaller households (MODEL-REF) and in the mornings and evenings (MODEL-REF), particularly when there are more speakers present (MODEL-REF).

As reviewed above, previous work on Mayan communities, including the Tseltal community suggests that Mayan children hear much TCDS from other children, and that the proportion of TCDS from other children increases with age (REFS). In order to analyze the effect speaker age (child or adult TCDS) together with the other predictors modeled above, we split the data into TCDS from adults and children. All other predictors remained the same, only the number of speakers present represented the number of speakers of the relevant type for that datapoint (i.e.„ TCDS rate from adults in clip 1 given the number of adult speakers present in clip 1).

The quantity of TCDS was strongly affected by speaker age: in contrast to prior work, these data show that most TCDS comes from adults (MODEL-REF). In addition, this model replicates the interaction between child age and time of day: older children hear most of their TCDS in the mornings and evenings while younger children hear stable TCDS over the day (MODEL-REF). We also find that speaker age effects depend on how many speakers there are of each type: while TCDS form children is more likely when more children are present, adults do not show a similar effect (MODEL-REF). The zero-inflation model of TCDS from adults and children included fixed effects of household size, time of day, and their interaction, but none of these predictors were significant.

The overall proportion of speech directed to the child (proportion TCDS) decreased when more speakers were present (MODEL-REF). Despite this, older children still showed a stronger time of day effect than younger children, with proportionally more TCDS in the mornings and evenings (MODEL-REF). There were no significant overall effects of age, nor were there any effects of maternal education or household size on the proportion of TCDS used.

Speech quantity during peak moments. Children's linguistic experiences are bursty (REFS) and, as we have seen, speech is distributed asymetrically throughout the day in Tseltal children's environments. If, for example, children do most of their language learning for the day during these short bouts of interaction, it may be more useful to characterize their learning environment with respect to the interactional periods—what kinds of speech do they hear during interaction?—rather than averaging over the entire day. We therefore repeat the same set of analyses with the turn-taking subset of the child's data: ODS rate, TCDS rate, TCDS rate by speaker age, and proportion TCDS.

During high turn-taking clips, Tseltal children heard an average of 25.21 minutes of speech per hour (median = 23.99; range = 12.94–38.29), of which an average of 13.28 minutes were directed toward the target child (median = 13.65; range = 7.32–20.19). Consequently, the mean proportion of speech directed to children was 0.62 (median = 0.62; range = 0.37–0.93).

Using the same approach as before, we modeled the four speech quantity measures for the 5–6 turn-taking clips[7] from each recording.

As in the random sample, when more speakers were present, ODS was significantly more frequent (MODEL-REF). While time of day significantly affected ODS rate in the random sample, its effect on the turn-taking bouts was only marginal, and trended in the opposite direction, i.e., more overheard speech during afternoon turn-taking bouts (MODEL-REF). Furthermore, there was no evidence of interactions between time of day and household size, as there was in the random sample. The zero-inflation model included fixed

[7] The turn-taking clips included in this analysis are: the five 1-minute turn-taking clips and also the 5-minute 'extension' clip for that recording if it was an extension of a turn-taking clip

effects of household size, time of day, and their interaction, but none of these predictors were significant.

The only significant factor affecting TCDS quantity in the turn-taking sample was a two-way interaction between child age and time of day (MODEL-REF). In contrast to the random sample this interaction showed that younger children hear more TCDS during morning and evening turn-taking bouts, but TCDS is more uniform across the day in older children's turn-taking bouts. Unlike the random sample, this turn-taking sample showed no main effect of child age: older and younger children heard comparable amounts of TCDS overall. There was also no significant interaction between age and number of speakers present, like there was in the random sample. The zero-inflation model included fixed effects of household size, time of day, and number of speakers, plus two-way interactions of time of day and household size, and time of day and number of speakers present. While, in the random sample, clips with no-vs-some TCDS were significantly predicted by house size, time of day, and the interaction of time of day and number of speakers, none of these factors significantly predicted the presence of TCDS in the turn-taking clips.

The model of TCDS quantity by speaker age for the turn-taking sample showed some similar results to the random sample. First, the quantity of TCDS in the turn-taking sample was strongly affected by speaker age (MODEL-REF) due to the fact that most TCDS still came from adults. Second, the presence of more children increased the quantity of TCDS from children more than the presence of more adults increased the quantity of TCDS from adults (MODEL-REF). However, TCDS quantity by speaker in the turn taking data also showed an inverse effect of time of day and child age, compared to that found in the randomly sampled data: TCDS was maximized during turn-taking bouts that took place in the mornings and evenings for younger children, but more uniform throughout the day for older children (MODEL-REF).

In addition, the turn-taking bouts also showed a significant effect of number of speakers: more speakers was associated with less TCDS (MODEL-REF). There was also an interaction between child age and speaker age: older children heard an increasing amount of TCDS from other children during turn-taking bouts (MODEL-REF). The zero-inflation model of TCDS from adults and children included fixed effects of household size, time of day, and their interaction, but none of these predictors were significant.

As in the random sample, the overall proportion of speech directed to the child (proportion TCDS) decreased when more speakers were present (MODEL-REF). Unlike the random sample, however, there was no interaction between child age and time of day. There were no other significant predictors of proportion of speech in TCDS.

Interactional exchanges

We can also measure children's linguistic environments as a summary of the interactional exchanges they partake in (see also Romeo REFS). When children are jointly engaged with an interlocutor, they can practice making contingent vocalizations, and both the child and the interlocutor can more easily coordinate their behaviors and social and communicative intentions. We characterize children's interactional exchanges with four measures: the rate of child-to-other turn transitions, other-to-child turn transitions, the average duration of interactional sequences, and the ratio of interlocutor vs. child vocalization time. We first describe these measures with respect to the random sample then, for comparison, examine the turn-taking sample.

Details about models here

Interactional exchanges during peak moments.

Frequency of high turn-taking activity

```
## Warning in bind_rows_(x, .id): binding factor and character vector,
## coercing into character vector
```

```
## Warning in bind_rows_(x, .id): binding character and factor vector,
## coercing into character vector
```

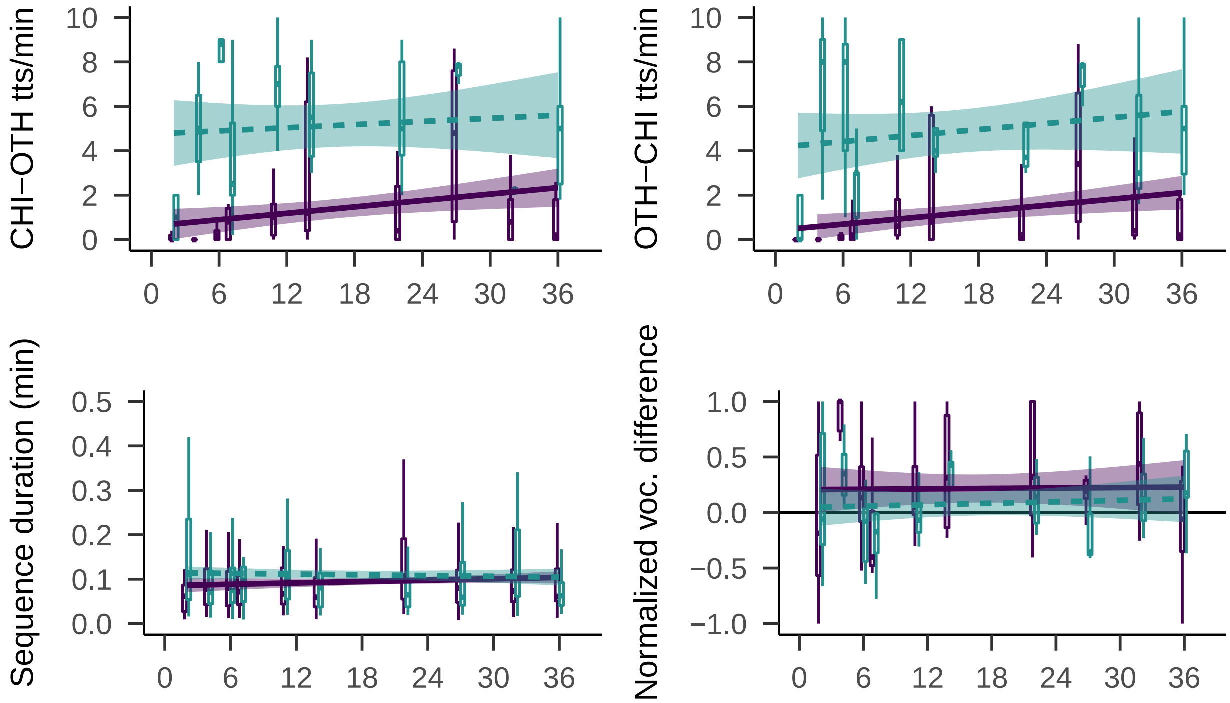


Figure 2. By-child estimates of minutes per hour of child-to-other (upper left) and other-to-child (upper right) turn transitions per minute, turn-taking sequenec duration (lower left), and normalized difference in vocalization time (1 = child vocalizes more than their interlocutor; 0 = vice versa). Data are shown for the random (purple; solid) and turn taking (green; dashed) samples. Bands on the solid linear trends show 95% CIs

```
## Warning in bind_rows_(x, .id): binding factor and character vector,
## coercing into character vector
```

```
## Warning in bind_rows_(x, .id): binding character and factor vector,
## coercing into character vector
```

Discussion

Future directions

Conclusion

Acknowledgements

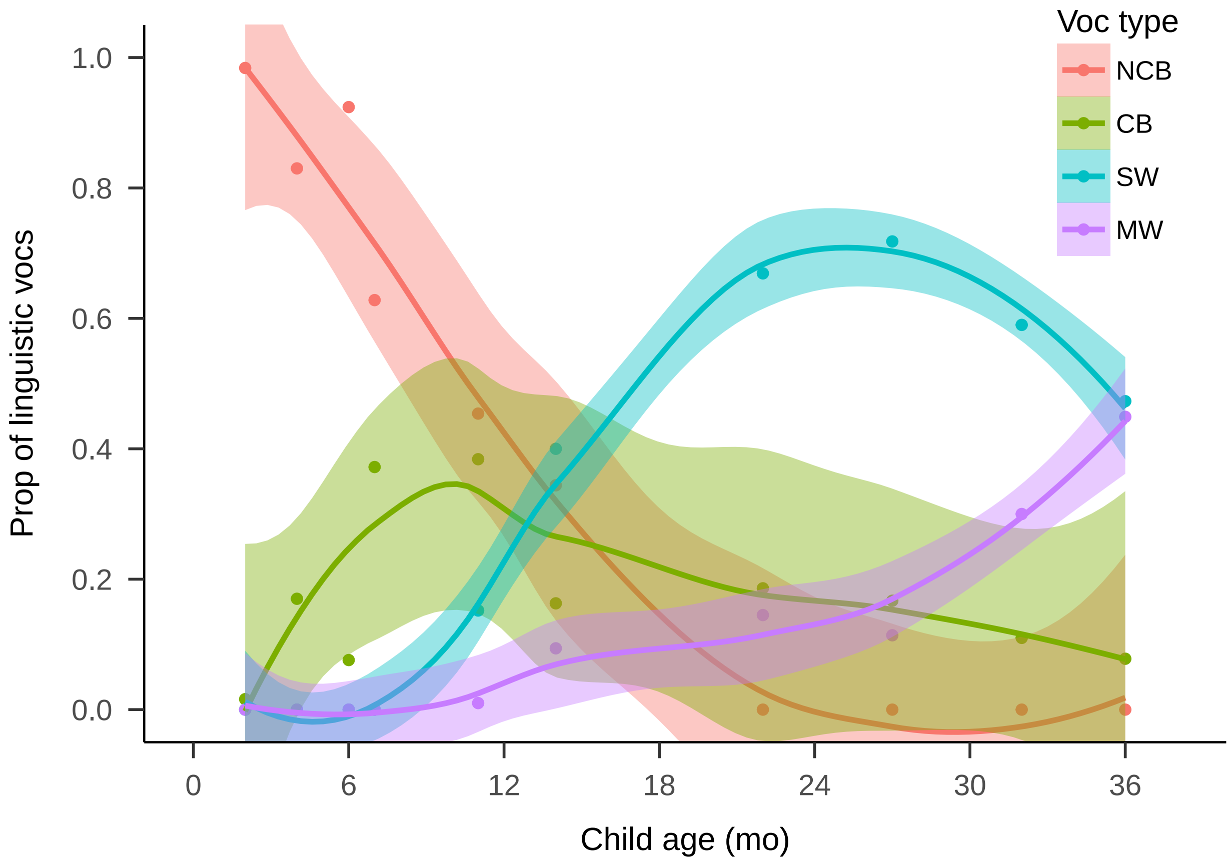


Figure 3

431 **References**