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]

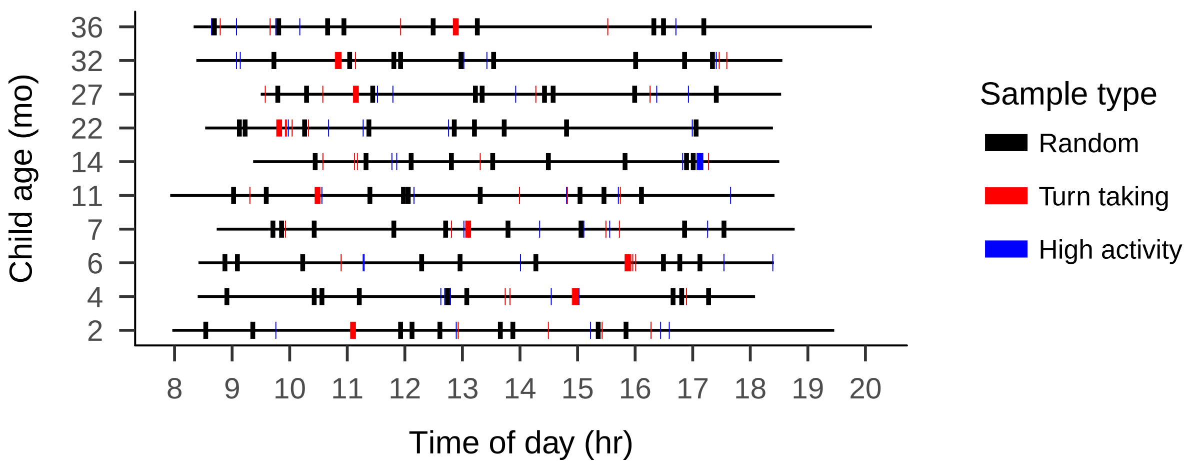
Data selection and annotation

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 three measures of speech quantity, three measures of verbal interactivity, and one measure of linguistic development. 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 and look at the potential relationship between how much speech children hear and their linguistic development.

Results

[TASK 14: change fits in the figures to reflect model estimates]

Data analysis

We investigated the quantity of speech children heard with two measures: the rate of speech directed to the target child ("TCDS" minutes per hour) and the rate of hearable speech directed to others ("ODS" minutes per hour) (see figure 1). We then briefly check two measures of the speaker environment: number of speakers, number of child speakers, and proportion of target speech from child speakers. We next analyze four measures of interactional quality: . Finally, we assess the children's vocal maturity.

[UPDATE ME TO REFLECT THE FINAL SET OF MODELS!] Notably these rate measures (TCDS and ODS min/hr) are zero-inflated, non-negative measures (i.e., between zero and infinity[5] with many cases of zero). This distributional property of TCDS and ODS min/hr renders them unsuitable for analysis with gaussian linear models because the variables are bounded at zero and, consequently, variance is systematically asymmetrical (i.e., a long right tail). We instead use zero-inflated negative binomial (ZINB) regressions for all rate variables in this manuscript. ZINB regressions model the dependent variable by splitting the data into two analyses: (1) a binomial ("zero-inflation") model that evaluates the likelihood that the variable is present (e.g., "TCDS" or "no-TCDS" for a clip) and (2) a negative binomial ("conditional") model of all the non-zero datapoints (e.g., "3" vs. "5"

[5]Minutes per hour are not capped at 60 because speech from all speakers is counted. For example, if two speakers are talking continuously throughout the sample, the estimate would be 120 min/hr.

TCDS min/hr). For proportion TCDS we used beta regression, which is suited to making predictions on doubly-bounded data. We implemented all of these models using the glmmTMB package in R (REFS; for more on bounded regression models see Smithson REFS). In models analyzing the random clips, we include all nine 5-minute clips, and in models analyzing the turn-taking clips, we include all 5–6 clips selected for their interactive properties.[6]

[UPDATE ME TO REFLECT THE FINAL SET OF MODELS!] Our primary predictors were as follows: child age (months), household size (number of prople), and number of non-target-child speakers present in that clip, all centered and standardized, plus maternal education (pre-secondary vs. secondary-plus)[7], 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 TCDS and ODS min/hr, we included number of speakers present, time of day, and their interaction to differentiate zero and non-zero cases across clips. We often had to reduce the fixed effects structure in the zero-inflation model to achieve convergence, as detailed below.

Speech quantity

Target-child directed speech (TCDS). The Tseltal children in our study were directly spoken to for an average of 3.63 minutes per hour in the random sample (median = 4.08; range = 0.83–6.55) and 13.28 minutes per hour in the turn-taking sample (median =

[6] 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

[7] Secondary school and beyond is Spanish-only.

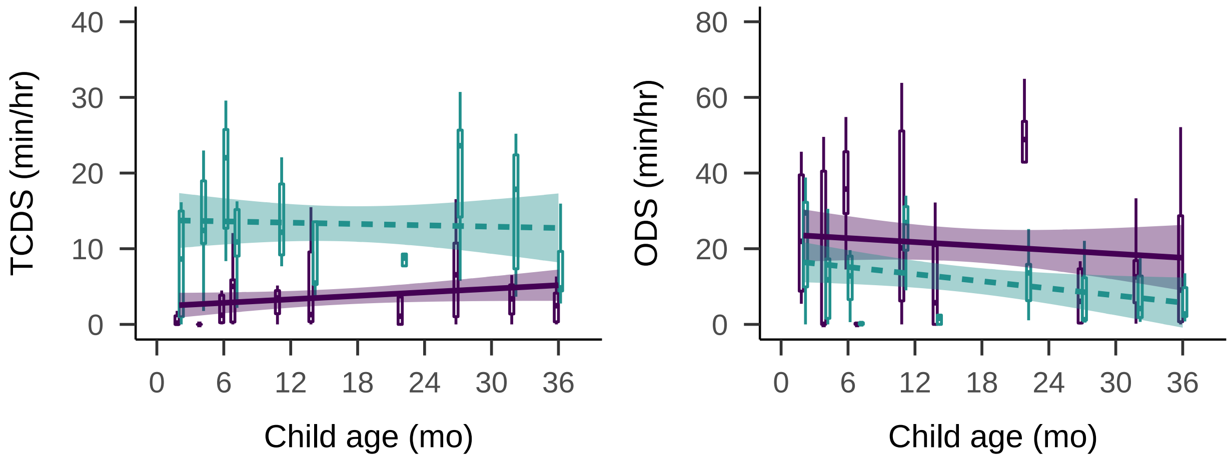


Figure 1. By-child estimates of minutes per hour of overheard speech (left), target-child-directed speech (right). Data are shown for the random (purple; solid) and turn taking (green; dashed) samples. Bands on the solid linear trends show 95% CIs.

13.65; range = 7.32–20.19).

The rate of TCDS was primarily affected by factors relating to the time of day. The conditional model of randomly sampled clips showed that, overall, children were more likely to hear TCDS in the mornings and evenings than around midday (MODEL-REF). However, in both the randomly sampled clips and the turn-taking clips, the conditional models showed that this pattern weakened for older children, some of whom even heard peak TCDS input around midday (figure 2; random: MODEL-REF; turn taking: MODEL-REF). There were no significant effects of child age, household size, number of speakers present, or maternal education in either model, and no significant effects in the zero-inflation models[8].

Other directed speech (ODS). The children in our corpus frequently heard speech directed to others: an average of 21.05 minutes per hour in the random sample (median = 17.80; range = 3.57–42.80) and 11.93 minutes per hour in the turn-taking sample (median = 10.18; range = 1.37–24.42). That is, on average during their daylong recording, children heard 5–6 times as much speech directed to others than was directed to them. Even

[8]The zero-inflation model for TCDS min/hr would not converge with time of day or number of speakers present.

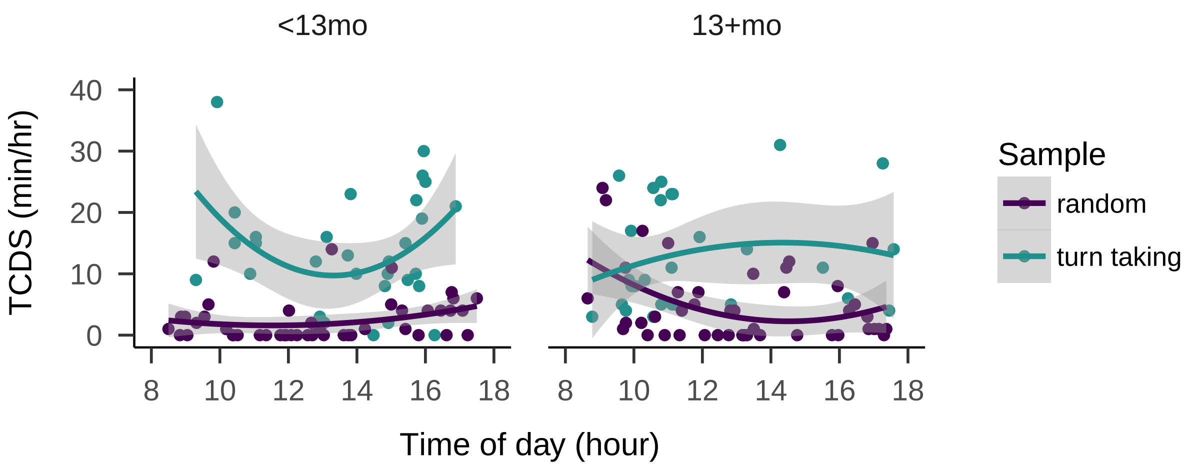


Figure 2. TCDS rate heard at different times of day by children 12 months and younger (left) and 13 months and older (right) in the randomly selected (purple) and turn-taking (green) clips.

in the period of maximal interaction, children heard nearly equal amounts of speech directed to them and speech directed to others.

The conditional models of ODS revealed a that the presence of more speakers was strongly associated with more ODS, in both the random (MODEL-REF) and turn-taking (MODEL-REF) clips. Additionally, more ODS occurred in the mornings and evenings (MODEL-REF), and was also more frequent in large households for older children compared to younger children (MODEL-REF). There were no other significant effects on ODS rate in the conditional models, and no significant effects in the zero-inflation models[9].

Speaker environment

As reviewed above, previous work on Mayan communities, including the Tseltal community suggests that Mayan children hear much of their TCDS from other children, and that the proportion of TCDS from other children increases with age (REFS). North American infants (6–7 months) tend to live in nuclear family homes but, during 16-hour

[9]Neither zero-inflation model for ODS min/hr would converge with number of speakers present, and so only include time of day.

daylong recordings, often hear speech from four individuals during a short period (REFS; cite{bergelsonetal2018daybyday}), and their developing ability to walk away and self-entertain has been proposed as a hypothesis for decreasing overheard speech with age (REFS; cite{bergelsoncasillas2018}). We investigated whether these same patterns held up for the children in the current corpus.

Number of speakers. There were an average 3.44 speakers present other than the target child in the randomly selected clips (median = 3; range = 0–10), and 2.56 non-target-child speakers present in the turn taking clips (median = 2; range = 1–6). Children accounted for a little less than half of the speakers present; the average number of child speakers in the randomly selected clips was 1.44 (median = 2; range = 0–5) and in the turn taking clips was 0.86 (median = 1; range = 0–4).

We modeled the number of speakers present in the randomly selected and turn-taking clips using poisson linear regressions due to the fact that the dependent variable is integer count data (REFS). Each model included random slopes of chils and the age-related predictors of interest—child age (standardized) and two-way interactions between child age and household size (standardized) and child age and time of day (centered on noon, squared, and then standardized). The fixed effects also included household size and and time of day again as nuisance variables.

There was no evidence of age-related change in the number of speakers present. The total number of speakers was only significantly affeced by the time of day in the random clips (MODEL-REF), and was not significanly influenced by any of the predictors in the turn-taking clips. We a second set of models, this time only analyzing the number of child speakers present and found parallel results to the first set of models (randomly selected clips: MODEL-REF; turn-taking clips: no significant effects).

Proportion TCDS from other children. Most TCDS heard by the children in our corpus came from adults: on average, only 19% of TCDS came from child speakers. We used a binomial model to evaluate whether the likelihood of hearing TCDS from a child in a clip increased with age (REF).[10] We found no evidence that TCDS from other children increased with age in the randomly sampled or turn-taking clips (MODEL-REF). We also performed a Spearman's correlation between the child's age and the mean number of child talkers, but neither showed a significant relationship (MODEL-REFS).

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. In what follows, we characterize children's interactional exchanges with four measures: the rate of child-to-other turn transitions (i.e., contingent responses to the child's vocalizations), the rate of other-to-child turn transitions (i.e., contingent responses by the child), the duration of interactional turn-taking sequences involving the target child, and the ratio of interlocutor vs. child vocalization time. We first describe these measures with respect to the random sample then, for comparison, we examine the turn-taking sample.

Contingent response rate.

Interactional sequences duration.

Vocalization ratio. We detect contingent turn exchanges between the target child and other speakers based on turn timing (). If there is a target-child-directed utterance that begins between the start of a target child vocalization and 2000msec after the end of the child's vocalization, we count it as a CHI-OTH turn transition Similarly, if there is a target child vocalization that begins between the start of a target-child-directed utterance and 2000msec after the end of the utterance, it is counted as a OTH-CHI turn transition. Each utterance is maximally allowed to act as one prompt for a child vocalization and one response to a child vocalization (e.g., in an CHI–OTH–CHI turn-taking sequence). We

[10] We were unable to run a beta regression on the proportion of TCDS with age given that most of the clip values were at or near 0 or 1; thereby motivating the binomial analysis reported here.

identify sequences of interaction using a similar mechanism: we look for chains of contingent responses before and after each child vocalization, allowing for speakers to continue with multiple vocalizations/utterances between speaker exchanges (). In this case, we also limit the overlap between utterances because we are focused here on interactional exchange that primarily features speech by one speaker at a time. Sequences are bounded by the earliest and latest vocalization for which there is no contingent prompt/response, respectively. Sequences must have at least one contingent non-target-child utterance. Finally, each child vocalization can only appear in one sequence, and many sequences have more than one child vocalization.

We base these timing restrictions on vocal contingency on prior studyes of infant and young children's turn taking. Hilbrink et al. (2015; REFS) found that infants' (0;3–1;6) responses to mothers typically began between -700ms and 1200ms relative to the end of the mothers' turns and mothers' responses to their infants began between -350ms and 650ms relative to the end of the infants' turns. Casillas et al. (2016; REFS) found that children's responses to caregivers' questions typically started between -500ms and 650ms relative to their caregiver's turn end, and caregivers' responses to children's question between -1000ms and 400ms relative to the children's turn end. Because both studies focused on fairly intensive bouts of interaction, and both within WEIRD parental contexts, we defined contingent responses in the current data with more generous allowances for overlap and gap (gap = 2000; overlap = 1000). That said, our timing restrictions are much tighter than those used to define interactional contingency in many other studies (e.g., REFS, see also REFS for a review on adult-adult turn timing).

Vocal maturity

Developmental trajectory.

Relation to language experience.

Discussion

Future directions

Conclusion

Acknowledgements

References

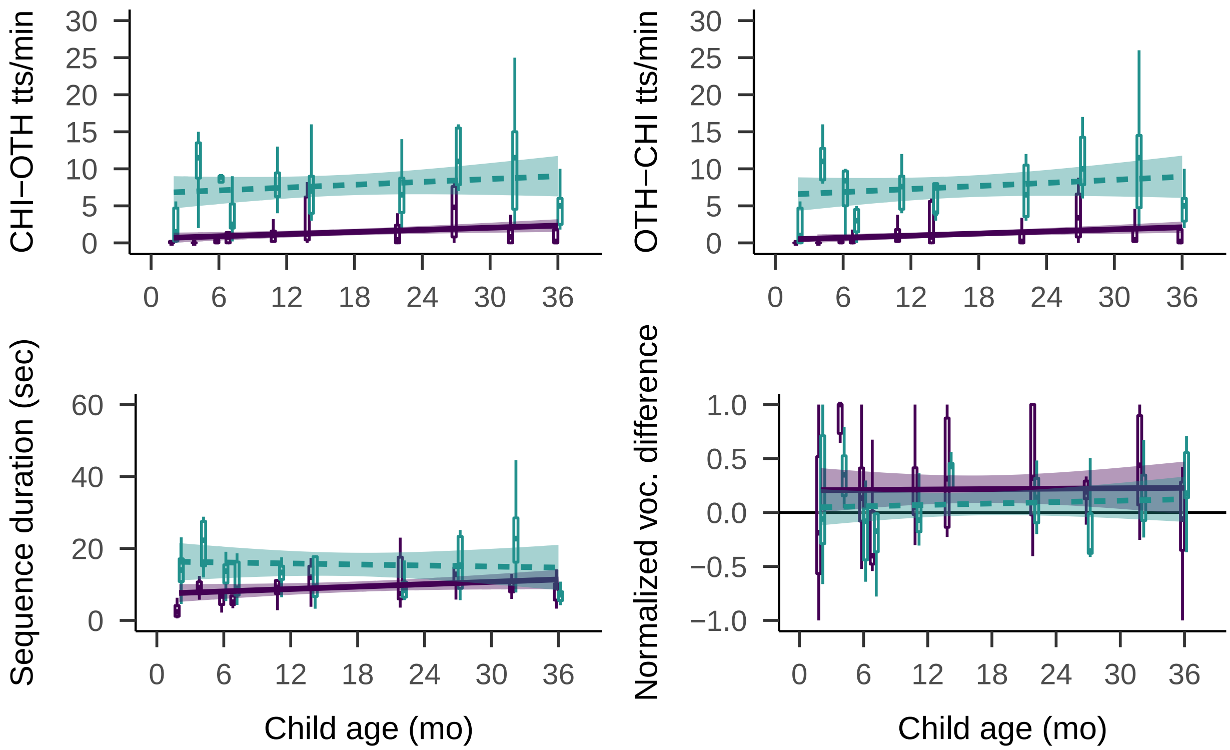


Figure 3. By-child estimates of contingent responses per minute to the target child's vocalizations (upper left), contingent responses per minute by the target child to others' target-child-directed speech (upper right), the average duration of contingent interactional sequences (lower left), and the ratio of vocalization time between target children and target-child-directed speech (lower right). Each datapoint represents the value for a single clip within the random (purple; solid) or turn taking (green; dashed) samples. Bands on the solid linear trends show 95% CIs.