“Am I my brother’s keeper?” The role of sibling caregivers in language acquisition

Joseph Coffey

1 - Background

The pervasiveness of Western, educated, industrialized, rich, and democratic, or “WEIRD” populations in psychological research has called into question how generalizable our theories of human development are across cultural settings (Henrich, Heine, & Norenzayan 2010). Within the field of developmental psychology specifically, 84% of participants in articles published in high impact journals between 2011 and 2022 were drawn from either the U.S. or Western Europe, despite only making up roughly 7% of the world population, with no evidence of increased diversification over this period (Singh et al., preprint). Much of the work that has been conducted in non-WEIRD populations suggests that cultural factors play an enormous role in determining children’s development (Nielsen & Haun 2016). In excluding these populations from research, we risk erasing the possibility that there may be many different paths to healthy development (Rogoff et al. 2017).

One area that has received increased attention in the wake of this call-to-arms is language input studies (Kidd & Garcia, 2022), which record the speech directed to young children from their mother or other primary caregiver in naturalistic or semi-naturalistic situations, such as meals or play sessions. Caregiver speech input is then coded for relevant measures of quantity (e.g., words per minute) or quality (e.g., word types per minute, length of utterance) and compared to a measure of their child’s language proficiency. Countless studies have found evidence that child-directed speech from caregivers plays an important role in language development (for review, see Anderson et al., 2021). Child-directed speech has repeatedly been found to mediate socioeconomic differences in early language growth, which is linked to later literacy and school achievement (e.g., Hart & Risley 1995; Hoff 2003; Rowe 2008). As a result, language input research has been applied to the design of educational policy (e.g., Wong, Boben, & Thomas, 2018) and interventions (e.g., Suskind et al., 2016) aimed at giving parents the tools to help their children reach their developmental potential.

Both theoretical conclusions (that child-directed speech from adults shapes early language development) and practical implications (getting parents to talk more to their children to improve children's ultimate academic outcomes) are clearly relevant to settings where most, if not all, caregiving is done by the parents, often just the mother. But what of the 43% of cultures in which mothers are *not* the child's primary caregiver (Barry & Paxson, 1971; Zukow-Goldring, 2002)? Even in the 57% of cultures in which mothers are reportedly the primary caregiver, often other people provide some of the care -- a phenomenon called *alloparental care*. From a practical viewpoint, when caregiving is thus distributed, chances for parental behavior to affect children's language are lower, diminishing the effect size of potential interventions (Fig. 1).

Figure 1: Whether parent interventions are less effective in societies with alloparental care depends crucially on the level to which children **actually attend to and learn from** speech input from others - a theoretical issue that needs to be resolved.

There have been significantly fewer studies on the effects of parent speech on language development in societies with greater alloparental care (e.g., Shneidman & Goldin-Meadow, 2012, Mastin & Vogt, 2015, Weber, Fernald, & Diop, 2017). One salient issue identified in recent work is the role of child caregivers (e.g., Loukatou et al., 2022): In some populations, primary caregivers are in fact older siblings or cousins that

are only a few years older than the young child themselves. In such settings, child-directed speech from adults is likely to be scarcer (as observed by Loukatou in a small scale study), leading to the prediction from current theoretical frameworks that infants cared for primarily by other children should have protracted language development compared to infants cared for primarily by adults (Lieven, 1994). **Resolving this issue requires studying input composition (who talks around and to the child) and its relation to child language outcomes in more diverse human populations, including those that are rural and/or non-industrialized.**

2 - Aims

We have four main goals:

1. Evaluating the accuracy of our novel speech classification system and employing machine learning to improve its ability to **identify and quantify speech automatically, with less bias towards English and urban environments**.
2. Describing input composition in a subset of WEIRD and non-WEIRD populations, chosen to have diverse caregiving distributions, specifically to address the question: **Who talks to and around the child?**
3. Describing child language outcomes in these same populations to address the question: **Do infants growing up in populations that rely more on child caregivers have protracted language outcomes?**
4. Describing child language outcomes to address: **Does the quantity of adult speech nonetheless predict children's language development, regardless of alloparental care amount?**

3 - Methods

a. Data Collection

A major contributor to the dearth of studies in communities with greater alloparental care is the challenges associated with implementing traditional methods. These communities are often difficult to access, which means large-scale sampling and long observation periods are unfeasible. In addition, because these studies rely on transcribed samples of speech, knowledge of the language is required to collect and analyze data. Because these languages are rarely spoken outside of their communities, producing these measures is incredibly difficult. Many of these societies are also multilingual, compounding the existing difficulties of transcription.

More recently, researchers have moved from such short observation periods to approaches relying on machine learning and speech technology, of which LENA is the most widely used (Casillas & Cristia, 2019). LENA provides automatic quantitative measures of child-directed speech by extracting periods of conversation and identifying speaker characteristics from many hours of consecutive audio. The measures produced by these systems have been shown to correlate with transcribed speech measures (Cristia, Bulgarelli, & Bergelson, 2020) and predict language outcomes in the same way (Wang, Williams, Dilley, & Houston, 2020). Since such systems capture children's input in their everyday environment, they are thought to better reflect the actual language interactions children have, providing both correlational (Ramirez-Esparza, Garcia-Sierra, & Kuhl, 2017) and intervention-based evidence (Ferjan Ramirez, Lytle, & Kuhl, 2020) for the importance of child-directed speech from adults in shaping children's early language. These systems clearly address the needs of cross-cultural work.

However, these systems also present implementational problems. Unlike children in much of the U.S. and Europe, children in more rural, less-industrialized, non-Western settings spend much of their time outside of the home, increasing the amount of possible noise from activity, weather, animals, and other factors that might confound speech classification. Language also poses a potential problem for speech quantity estimates: because LENA was trained on urban-dwelling American English learners growing up in nuclear families, there is no guarantee that it

will be as effective when used on unrelated languages or in rural settings with extended families. Finally, the most used systems for taking daylong recordings are expensive, reducing their accessibility to communities and scientists that may wish to make use of them. The proprietary nature of these systems can also impede analysis due to security constraints on data access. Because of the impact expanding the use of daylong recording systems into studies of language acquisition in the developing world would have, it is important that such systems be both accurate and accessible. **We hope to address this need by evaluating the effectiveness of a novel daylong recording system across cultural settings, which we refer to as USB+VTC.**

Figure 2: USB recording device (left); Child wearing the device in a small shirt pocket (right)

USB+VTC (Fig. 2) is a method that uses a voice-type classifier, an audio processing software that uses an end-to-end neural network to automatically classify speech (Baranov et al., 2022). Unlike LENA, VTC is open-source and freely available. VTC was also trained on a variety of different non-English speech corpora, including many from societies with high degrees of alloparental care and where children are often outside (e.g, Tsimane, Namibia), including at least one society where multilingualism is typical (i.e., Vanuatu). In one study, VTC was also shown to outperform LENA when identifying speaker categories (i.e., Female Adults, Male Adults, Key Child, and Other Children) on a common set of English speech data (Lavechin et al., 2020). Rather than purchasing specialty devices, researchers can instead purchase cheap, mass-produced USB audio, further reducing the cost. Overall, USB+VTC presents many solutions to problems introduced by traditional daylong recording systems.

b. Participants

In our studies, we will be reusing datasets collected using USB+VTC: one in a Western European country, and the other in a recently independent country in Southeast Asia. Data transfer agreements will be signed to ensure data protection complying with GDPR, and reuse will follow best ethical practices. **Our inclusion of two datasets will allow us to directly compare language input and outcomes in the presence and absence of alloparental care practices.**

The first dataset comes from a randomized controlled trial conducted by Dr. Carlo Barone in the Lab for Interdisciplinary Evaluation of Public Policy at SciencesPo. The study will include at least 50 families recruited in Ile-de-France with the treatment group receiving information enabling parents to more frequently engage in book-reading and other activities promoting early child literacy. Recruitment will target mostly low-income Francophone families with both native and immigrant backgrounds who have preschool-age children. Initial data collection will begin in the summer of 2023, with some data available by the start of the present project.

The second dataset comes from an ongoing randomized controlled trial conducted by Victoria Baranov at the University of Melbourne. The study focuses on 288 children (aged 1-4) in Timor Leste (Fig. 3), a relatively new Southeast Asian country bordering Indonesia whose sovereignty was recognized in 2002 after years of conflict. In this study, half of parents viewed videos that explained the potential impact

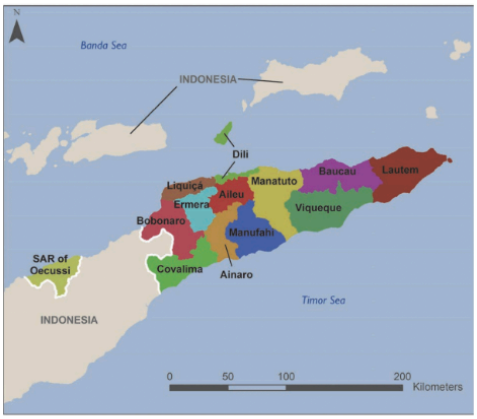

Figure 3: Timor Leste

on language of talking more to one's child. Families were drawn from both urban and rural regions of the country and have limited formal education. They report relatively large household sizes and were surveyed on sibling participation in childcare (Fig. 4). The post-treatment data collection is planned for this summer, and should be fully available by the start of the present project.

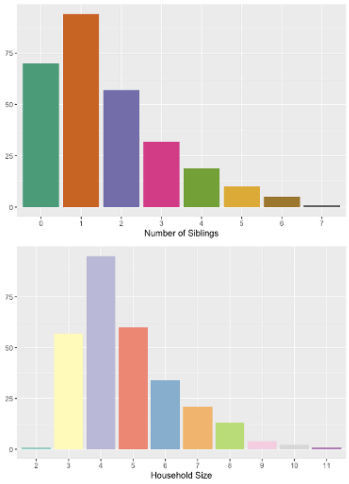

Figure 4: From Timor Leste: Number of siblings at home (top); Total household size (bottom)

4 - Proposed studies

a. Study 1: Classifying and quantifying speech automatically, with less bias towards English and urban environments.

While LENA has been shown to predict individual differences in language acquisition in mostly urban Western populations (Wang, Williams, Dilley, & Houston, 2020), much less work has been conducted in other settings (e.g., Weber, Fernald, & Diop, 2017). To ensure that our device can accurately track speech in rural settings as well as in urban settings, **Study 1** will consist of a human validation of the corpora produced by our two data sets. We will be using annotation methods in accordance with ACLEW guidelines (Bergelson et al., 2017; *https://osf.io/b2jep/*), which outlines a schema for identifying speaker characteristics for the purpose of comparison with the outputs of speech diarization programs. Although there have been similar validations of the LENA system conducted in the past, only one included data from outside of urban Western settings (meta-analyzed in Cristia et al., 2020). As of yet, there has been no systematic validation of the USB+VTC outside of its diverse training set.

We will randomly sample audio from our recordings and have a human assistant annotate frames of speech according to speaker identity. Using the human annotation as our "gold standard" we will determine the effectiveness of our method by measuring the accuracy of the VTC automatic annotation. We will then compare annotation accuracy across our French and Timorese samples to determine whether there is differential performance based on setting and living environment (see Fig. 5). We predict that because VTC was trained on data collected from societies comparable to both our French and Timorese samples, we will not notice any difference in accuracy between our two samples.

However, should this validation reveal differences in performance, this would indicate that the algorithm is biased, a known issue in machine learning that often occurs when one class (e.g., one speaker type) is less frequent than another in a dataset. We will retrain VTC trying different methods that have been developed in machine learning to deal with data biases, including oversampling low-frequency classes to better balance their presence in the dataset, or giving more weight to observations coming from the low-frequency classes (Fletcher, Nakeshimana, & Olubeko, 2021). As applied to our dataset, this might include oversampling or weighting more heavily instances of Other Child speech, which might be more frequent in our Timorese sample but underrepresented in the training dataset as a whole relative to

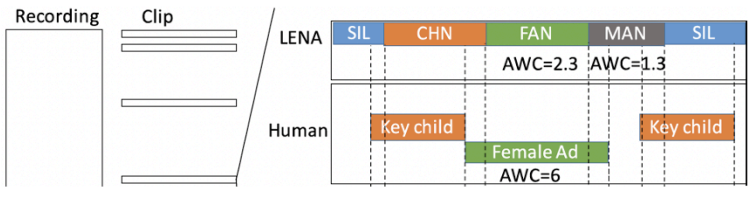

Figure 5: Example of our validation procedure, from a previous evaluation of LENA (Cristia et al., 2020). Clips are randomly sampled from a recording, then a human annotator identifies speakers in the clip. LENA outputs are then compared for accuracy.

adult speech. We will then submit a manuscript of our results to a methodology journal such as *Behavior Research Methods* or *Interspeech*.

b. Study 2: Who talks to and around the child?

In rural, non-Western societies, children have often been found to have more access to speech from siblings and peers than is typical in urban Western settings (Shneidman et al., 2012; Weber, Fernald, & Diop, 2017; Cristia, Dupoux, Gurven, & Stieglitz, 2019; Loukatou et al., 2022). However, the prevalence of sibling speech has been debated (see Casillas, Brown, and Levinson, 2019, 2021). As a result, we believe it is important to collect speech between urban Western and rural non-Western societies using the same methodologies to enable direct comparison. To this end, **Study 2** will use USB+VTC to track speech in children's environments according to the categories mentioned previously (Female Adult, Male Adult, Target Child, and Other Child). We will compare the frequency of these speech categories across our two settings to determine whether setting and family composition produce different early speech environments for young children. We will also compare our data to other studies that use automatic daylong recording to collect speech to determine whether these settings fall in line with norms established in other comparable societies (e.g., Casillas, Brown, and Levinson, 2019).

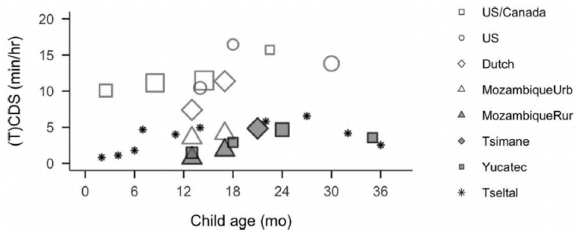

Figure 6: From Casillas, Brown, & Levinson (2019) – Estimated child-directed speech per hour from adults across a range of Western (e.g., US, Canada) and non-Western societies (e.g., Mozambique, Tsimane).

We expect to find less speech from adults overall in Timor Leste as compared to France. Studies that have directly compared speech collected in urban Western settings to speech in less urbanized non-Western settings have often found that adults generally speak to children less (e.g., Shneidman & Goldin-Meadow, 2012; Mastin & Vogt, 2015). We believe that a contributing factor to this phenomenon may be the prevalence of speech from sibling caregivers. As a result, we expect to find more speech from Other Children in Timor Leste as compared to France, where family sizes are generally smaller and caregiving from siblings is less common. We expect to find our total speech in France and Timor Leste to be comparable to totals found in other urban Western settings and in other less urban non-Western societies respectively (see Fig. 6). We intend to submit a manuscript of our findings to a journal focused on developmental psychology, such as *Developmental Science* or *Child Development.*

c. Study 3: Do infants growing up in populations that rely more on child caregivers have protracted language outcomes?

Studies of language outcomes rarely consider input from siblings, which is rare in urban Western settings. Some have posited that speech from other children may not be suitable to learn from (Lieven, 1994). At least one study of a Yucatec Mayan community in Mexico, where sibships are large and sibling caregiving is common, failed to find a relationship between sibling speech and language outcomes (Shneidman & Goldin-Meadow, 2012). However, other studies have found evidence of older sibling input effects on younger sibling language outcomes, most notably in immigrant households in the U.S. (Bridges & Hoff, 2014; Duncan & Paradis, 2020). Given the contentiousness of these claims, we will be examining the effects of sibling caregiving directly in **Study 3**.

First, we will derive a measure of children's language development by examining Target Child vocalizations in our recordings. The average length of each Target Child's utterances (as calculated by canonical syllables) will be used as a measure of language ability that can be used and compared across our French and Timor Leste samples.

We expect to find one of two results: if sibling speech is as suitable as adult speech to learn from, we would expect to find no difference between our two groups ***given a comparable amount of total speech heard.*** Namely, if the amount of adult speech and sibling speech in Timor Leste is the same as the total amount of adult speech in France (where we expect to find very little sibling speech), we would not expect to find large differences in language complexity. However, if sibling speech is not an equal substitute for adult speech, we would expect to find less complex speech in our Timor Leste sample.

Because there could be many extraneous variables that could also contribute to language differences between our French and Timorese samples (e.g., parent education, unmeasured cultural differences), we will also be looking for differences in sibling speech exposure within our Timorese sample only. We will compare our measure of language ability to caregiver responses to a questionnaire about daily activities. Parents were asked the following: "How often does your eldest child help you take care of your children? 1. Every day, for a large part; 2. Every day, a little; 3. A couple of times a week; 4. Once a week; 5. More than once a month; 6. Less than once a month; and 7. Never." We expect that households who rely more on their older children for caregiving will produce more speech from Other Children in our recordings. If sibling speech is appropriate for children to learn from, we expect to find no difference in language ability based on these responses. If sibling speech is not appropriate for children to learn from, we expect that children from households with more older sibling caregiving will have less complex speech.

If, in **Study 2**, we find sufficient differences in input across individuals, we can also investigate whether the amount of sibling speech children hear throughout the day predicts their language outcomes. We would do so by comparing children's language outcomes to the amount of speech from Other Children they hear throughout the day. Our predictions are the same as previously stated. We intend to submit a manuscript of our findings to a journal focused on developmental psychology, such as *Developmental Science* or *Child Development.*

d. Study 4: Does the quantity of adult speech nonetheless predict children's language development, regardless of alloparental care amount?

Finally, in **Study 4** will be examining the influence of adult speech on children's language development in both our French and Timorese samples. We expect to find adult speech to be predictive of children's language outcomes regardless of alloparental care, as has been found in many other Western (Wang, Williams, Dilley, & Houston, 2020; Anderson et al., 2021) and non-Western settings (Shneidman & Goldin-Meadow, 2012; Mastin & Vogt, 2015; Weber, Fernald, & Diop, 2017). We intend to submit a manuscript of our findings to a journal focused on developmental psychology, such as *Developmental Science* or *Child Development.* However, because we anticipate a wider audience may be interested in these findings, we might instead submit to *Proceedings of the National Academy of Sciences*.

5 - Personal Experience

I am broadly interested in how young children learn language from the people they grow up around. My dissertation focuses on examining different predictors of early word-learning. For example, I studied child-directed speech and vocabulary growth in a cohort of internationally adopted children. Because adopted children are not biologically related to their caregivers, we were able to examine the role of caregiver speech on language development while controlling for genetic confounds (i.e., verbal parents may have verbal children) present in nearly every other input study (Coffey et al., 2022). I am also working with the Abdul Latif Jameel Poverty Action Lab and Innovations for Poverty Action in Ghana on a longitudinal randomized control trial on the

impact of parent secondary education on children's development, which included the use of LENA to predict language and cognitive outcomes in children aged 1-3 years (Coffey, Zhan, & Spelke, 2023). We will be submitting a validation of our language and cognitive assessment battery soon. Finally, I will be conducting a meta-analysis of studies relating parent input to child language outcomes. In particular, we will be looking for factors that might moderate the size of this relationship across studies (e.g., input and vocabulary measures, SES, child age, etc.). I am also currently in the data collection phase for a project focusing on children's ability to learn new words from their older siblings, and how this compares to learning from their parents. While I am only running the study on children in Boston at the moment, I hope to be able to expand my procedure to settings where child caregiving is more common. My research experiences have prepared me well for the many facets of this project. In undertaking this project, I am excited to not only expand my work to new cultures (Timor-Leste, France) but also to new methodologies, as I learn more about the machine learning techniques underlying our daylong recording systems. Ultimately, I hope to continue pursuing socially-impactful work that also carries theoretical importance to the study of human development.

6 - Supporting the Mission of the Fyssen Foundation

The mission of the Fyssen Foundation is to study the emergence and development of cognitive mechanisms that underlie human behavior. My project focuses on the development of one of our most unique abilities as humans: language. Despite the sheer range of radically different environments children are born into, nearly all of them will grow up to be proficient speakers of their native language, (and often, languages). I believe that in order to better understand the underpinnings of our capacity for language, we must study the features of these environments that make learning possible, which may differ greatly from culture to culture. I take an interdisciplinary approach in our studies, bringing insights from psychology, linguistics, and machine learning to bear on our questions. My project not only has the potential to make theoretical contributions to the field, but it also promises to produce important tools for the study of language development. These tools are relevant to academic anthropologists, psychologists, and linguists, as well as economists, policymakers, and community leaders conducting interventions targeting early childcare and education.

7 - Timeline

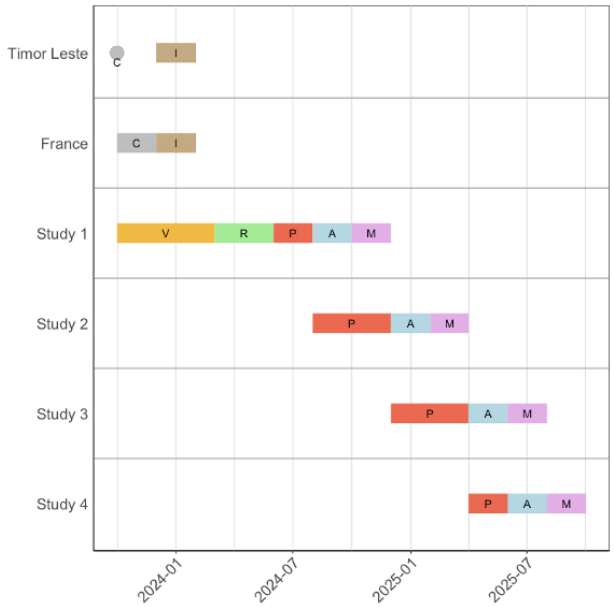

Figure 7: Data (C)ollection, Data (I)ntegration, (V)alidation, (R)etraining, (P)reparation, (A)nalysis, (M)anuscript

(Fig. 7) Before the appointment, the Timorese data will be collected and the French data will be nearing completion. We will immediately begin validation of the Timorese data for **Study 1**, followed by the French data. When both are finished, we will begin integrating our datasets for retraining the VTC based on our findings. We will then start preparing for our analysis (i.e., literature review, study registration, etc.). Because we cannot interpret our speech data before retraining, we will not begin **Study 2** until we have reached the end of this phase for **Study 1**. We will then prepare our data for **Study 2** by calculating speech totals from each of our recordings and then move to analysis. Following our analysis, we will repeat this process with **Study 3** for our child language outcomes and **Study 4** for adult language. We plan to produce four manuscripts by the end of the appointment.

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