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Little evidence for a noun bias in Tseltal spontaneous speech

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Abstract

This study examines whether children acquiring Tseltal (Mayan) demonstrate a noun bias – an overrepresentation of nouns in their early vocabularies. Nouns, specifically concrete and animate nouns, are argued to universally predominate in children's early vocabularies because their referents are naturally available as bounded concepts to which linguistic labels can be mapped. This early advantage for noun learning has been documented using multiple methods and across a diverse collection of language populations. However, past evidence bearing on a noun bias in Tseltal learners has been mixed. Tseltal grammatical features and child–caregiver interactional patterns dampen the salience of nouns and heighten the salience of verbs, leading to the prediction of a diminished noun bias and perhaps even an early predominance of verbs. We here analyze the use of noun and verb stems in children's spontaneous speech from egocentric daylong recordings of 29 Tseltal learners between 0;9 and 4;4. We find weak to no evidence for a noun bias using two separate analytical approaches on the same data; one analysis yields a preliminary suggestion of a flipped outcome (i.e. a verb bias).

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We discuss the implications of these findings for broader theories of learning bias in early lexical development.

Keywords
Tseltal, Mayan, lexical development, vocabulary, noun bias, daylong recordings

Introduction

Words for objects predominate in children's early vocabularies – especially words for concrete objects and names for people (Gentner, 1982, 2006; Gentner & Boroditsky, 2001; Gleitman, 1990; Nelson, 1973). This tendency, termed the 'noun bias', has been proposed as a universal feature of early language development – one that gives children a foot in the door to more complex parts of the language system (Au et al., 1994; Bassano, 2000; Caselli et al., 1995; Gentner & Boroditsky, 2001, 2008; Jackson-Maldonado et al., 1993; Tardif et al., 1997, 1999; see also Baillargeon, 1993; Soja et al., 1991; Spelke, 1985, 1990). Gentner's (1982, 2006) natural partitions/relational relativity hypothesis (NP/RR) proposes that the noun bias arises because objects are perceptually given as individuable concepts, even to infants. In contrast, relational concepts (such as actions on objects) must be linguistically selected before they can achieve individuability. On this view, concrete objects are conceptually low-hanging fruit, ready to be mapped to corresponding linguistic labels. Meanwhile, relational concepts tend to become available more gradually, and so only become ready for a corresponding linguistic label later on.

Prior research examining the noun bias has typically taken one of three approaches:

1. **Novel word learning in an experimental context:** We can examine the conditions under which children learn new object and action words. For example, U.S. toddlers expect that novel words refer to objects over actions (Waxman, 1991; Waxman & Hall, 1993). They also learn new nouns more readily than new verbs, even if the children are highly attentive to the novel actions demonstrated (Childers et al., 2020, 2022; Imai et al., 2008);
2. **Proportion or ratio of syntactic types in children's vocabularies:** A more traditional approach is to examine children's natural vocabulary development. For example, across six languages, Gentner (1982) found that nouns made up ~50%–85% of the word types in children's early productive vocabularies, while predicates (including verbs) only made up ~0%–35%. Many other studies have since followed suit (e.g. Setoh et al., 2021; Tardif et al., 1997, 1999). In some cases researchers based these calculations on spontaneous child speech, but in other cases calculations were based on parent-reported child vocabulary;
3. **Relative representation of syntactic types in children's vocabularies:** Inspired by E. Bates and colleagues' (1994) analyses of the MacArthur Bates Communicative Development inventory ('CDI', a vocabulary checklist; E. Bates et al., 1994, 1995; Fenson, 2007), a third approach has been to test whether a word class is over- or under-represented relative to a child's total vocabulary size.

> This approach captures the intuition that if a child has acquired 10% of their overall vocabulary but has acquired 20% of their nouns, the nouns are relatively overrepresented. Using this approach, recent work by Braginsky, Frank, and colleagues found a consistent noun bias in the parent-reported productive vocabularies of children across 27 languages (Braginsky et al., 2019; Frank et al., 2021).

We focus in the present article on non-experimental approaches, among which the second and third approaches have complementary strengths. The second approach (proportional frequency measures) can be based on highly naturalistic spontaneous speech data, vocabulary checklists, or a combination, but does not directly measure over-/under-representation of word classes. The third (relative representation) approach gives a clear-cut method for measuring over- and under-representation, but has only been attempted with parent-reported vocabulary data, which limits its ecological validity and cross-linguistic applicability (checklists exist in a more limited number of languages than spontaneous speech corpora).

In the present study, we use both of these approaches with spontaneous speech data to examine the evidence for a noun bias in children acquiring Tseltal (Tenejapan geolect; Mayan; Chiapas, Mexico). As we will discuss below, the proposed universality of a conceptual object bias, while well motivated, is undermined by limited data on non-Indo-European languages, especially smaller-scale languages. We will argue that Tseltal is a particularly informative test case for the universality of the noun bias, considering that both linguistic and cultural factors may lead Tseltal children to acquire verbs as readily as nouns, if not more readily. In what follows, we briefly review prior evidence regarding a universal noun bias, with particular attention to prior work on Mayan languages (including Tseltal), before diving into the methods and findings of the present study.

The noun bias: a brief overview

Cross-linguistic evidence generally favors the noun bias, but tells a complicated story. Evidence in favor of a noun bias in children's productive early vocabularies has been found across an array of languages – most are Indo-European*[1] – including English*, German*, Swedish*, Norwegian*, Danish*, Italian*, French*, Spanish*, Portuguese*, Greek*, Croatian*, Latvian*, Czech*, Russian*, Slovak*, Turkish, Hebrew, Japanese, Korean, Mandarin, Cantonese, Kiswahili, Kigiriama, and Kaluli (see, for example, Braginsky et al., 2019; Frank et al., 2021; Gentner, 1982; Imai et al., 2008; Pae, 1993; Setoh et al., 2021; Snedeker et al., 2003; Tardif et al., 1997, 1999). Among studies that directly compare word learning across two or more languages, partial evidence for a noun bias has been found using all three data types mentioned above: experiment-based word learning (Imai et al., 2008; Snedeker et al., 2003), naturalistic speech production (Gentner, 1982; Setoh et al., 2021; Tardif et al., 1997, 1999), and vocabulary checklist data (Braginsky et al., 2019; Gentner, 1982; Tardif et al., 1999). Importantly, these comparative studies raise the possibility that, even if the noun bias is universal, it arises more weakly in some languages and more strongly in others.

Among non-Indo-European languages, Mandarin and Korean have been studied most often for a noun bias, with work using vocabulary checklists, diary studies, spontaneous

speech, and experiments, and with study designs that have either cross-sectional or longitudinal age samples of young children (e.g. both languages: Braginsky et al., 2019; Frank et al., 2021; and Mandarin: Setoh et al., 2021; Tardif, 1996; Tardif et al., 1997, 1999, 2008; Xuan & Dollaghan, 2013; and Korean: Au et al., 1994; Bornstein et al., 2004; Chang-Song, 1997; Choi, 2000; Choi & Gopnik, 1995; Gopnik & Choi, 1990; Gopnik et al., 1996; Kim et al., 2000; Pae, 1993). Among these studies there is both evidence in favor of and evidence against a noun bias. In some cases, the findings support an early predominance of nouns but also support a relative advantage for learning verbs, compared with English speakers, or compared with the same children's English vocabularies (the latter for English–Mandarin bilinguals; Setoh et al., 2021; Xuan & Dollaghan, 2013).

Among indigenous and smaller-scale language populations, we are only aware of evidence directly engaging with the noun bias debate from Tseltal (Mayan), Tsotsil (Mayan), Navajo (Athabaskan-Eyak-Tlingit), and Kaluli (Trans-New Guinea). With two exceptions – Brown et al. (2005) and Gentner and Boroditsky (2008) – data for these languages come from transcriptions of spontaneous speech. The Navajo data were gathered as caregiver-reported vocabulary via an adaptation of the CDI made by a team of Navajo speakers and scholars (Gentner & Boroditsky, 2008), and were found to support a noun bias. The Kaluli data, gathered originally by Schieffelin (1979), were subsequently analyzed by Gentner (1982) via English translations of the original transcripts – these also favored a noun bias (Gentner, 1982, 2006). Data from the two Mayan languages (discussed further below) argue against a noun bias, in favor of a verb bias instead (Brown, 1998, 2008; De León, 1999a, 1999b, 2001; but see discussion below). Overall then, among smaller-scale and indigenous languages, evidence for a noun bias is mixed.

The noun bias in Mayan languages

Mayan vocabulary development has played a special role in this noun bias debate; it has brought some of the only detailed linguistic analyses from small-scale language communities, motivated by both cultural and linguistic factors that may promote early verb learning. Evidence from two Mayan languages in particular, Tseltal and Tsotsil, has made essential contributions to this debate (Brown, 1997, 1998, 2001, 2007, 2008; Brown et al., 2005; De León, 1999a; 1999b, 2001; Pye et al., 2007). The interactional norms of child–caregiver communication and the linguistic structure of both languages heighten the salience of verbs and diminish the salience of nouns in children's linguistic input. For example, in Tseltal, the basic Verb–Object–Subject (VOS) word order puts verbs in a highly salient position. Furthermore, arguments that are cross-referenced on the verb are routinely dropped such that many utterances comprise a single, inflected verb. In terms of morphosyntactic complexity, nouns and verbs are on more equal footing than in English and other languages, because the obligatory inflectional morphology on nouns and verbs is highly regular and phonologically similar, which allows children to develop a morphological segmentation strategy that applies well to both word types. There are also many, frequently used 'specific' verbs – these are transitive verbs that are highly constrained in what patients they take and so are highly concrete in their semantics (e.g. Tseltal *ti'* for 'eat/bite-[meat]'). In contrast, inanimate nouns tend to refer to

unindividuated material, running counter to the simple, individuated object-to-label mapping assumed as part of the NP/RR hypothesis. Finally, adult caregivers are observed to only infrequently label objects for children, more often talking about relational context or commenting socio-interactively on the child's behavior (Brown, 1998, 2011, 2014; De León, 1999a, 1999b, 2001).

Indeed, Brown's (1998) longitudinal and in-depth investigation of two children's early spontaneous speech found evidence for a facilitation of early verb learning and no evidence for an early noun bias. She examined both children's spontaneous speech from monthly 2-hour audio recordings and additional video recordings every 6 weeks throughout the sampling period (ages 1;3–2;3 and 1;5–2;5). At the earliest stages of morphosyntactic development (MLU 1.0–1.5), children's speech revealed similarly sized noun and verb inventories. Over time, the children's verb inventories began to overtake their noun inventories (ending at MLU = 1.7; 54%–59% verbs; 53%–57% verbs, when proper nouns are included).[2] She also found that, among children's multimorphemic utterances, verb utterances (e.g. inflected verbs) outpaced noun utterances (inflected nouns, compound nouns). Then, diving further into the children's morphosyntactic acquisition, she found that, by the end of the observation period (MLU = 1.7), they had partial productive command of some ergative prefixes and absolutive suffixes. This suggests that Tseltal children at the early stages of speech production have already begun to develop abstract morphosyntactic systems that can simultaneously aid noun and verb learning. Children also showed early evidence of the benefactive suffix and obligatory and nonobligatory aspect marking, but not yet systematically. Notably, many of the children's verbs were specific verbs, that is, transitive verbs that are highly restricted in the patients they take. So in a nutshell, in two children's early spontaneous speech, she found no initial noun bias (with proper nouns excluded), then a rapid growth in verb inventory, and evidence of inflectional morphology use that suggests early abstract morphosyntactic learning. These data suggest a striking early capacity for verb learning in Tseltal-acquiring children.

These findings are strengthened by qualitatively similar patterns in the in-depth longitudinal analyses of two children's early Tsotsil productions (MLU 1–2.75; De León, 1999a, 1999b, 2001). For example, nouns never surpassed the 50% mark in the Tsotsil children's early productive vocabularies (even when including proper nouns and kin terms), and multimorphemic utterances were far more likely to be verb utterances than noun utterances. Given that Tsotsil is a closely related Mayan language to Tseltal and shares many of the same linguistic and interactional factors supporting early verb learning, we can treat these Tsotsil findings as a very close second source of data on the existence of a Tseltal noun bias. Together, the two studies form a strong case against a more general Mayan noun bias. Their findings are consistent with verb learning's centrality in research on Mayan language acquisition; across a range of Mayan languages, children consistently use verbs in their early productions and quickly show variation in verb use and inflection (e.g. Brown et al., 2013; Mateo Pedro, 2015; Pfeiler et al., 2003; Pye, 1985; Pye et al., 2017). In other words, verb learning is the obvious site for examining early lexical and morphosyntactic development in Mayan languages.

However, these findings come exclusively from examinations of spontaneous speech, while the noun bias has most consistently shown up in analyses of vocabulary checklist

data (see, for example, Gentner & Boroditsky, 2001). One study has attempted to address this: Brown et al. (2005) composed a preliminary vocabulary checklist of 594 words for Tseltal, based broadly on the CDI (283 nouns, 207 verbs, 104 other words; see Gentner, 2006 for a full description). They then collected caregiver reports for five young children's vocabularies, finding a uniformly higher presence of nouns than verbs in both proportion of nouns ($M = 0.57$, range = 0.54–0.62) and noun–verb ratio ($M = 1.34$, range = 1.17–1.63). Notably, words for animate beings made up nearly a third of the nouns. Consistent with Brown's (1998) study of spontaneous speech, they also found a relatively high proportion of verbs, suggesting that, even with evidence of a noun bias, Tseltal children still showed rapid verb learning relative to children in other languages studied.

While these data represent a truly remarkable effort to collect vocabulary checklist data for Tseltal, the sample size is still quite small ($N = 5$), the questionnaire was not validated, and the researchers encountered challenges in both selecting specific word forms and in eliciting assured responses from caregivers (e.g. which verb inflections to use, how much context to provide, how to administer the survey). Methods alone cannot easily explain the discrepancy between these checklist findings and Brown's (1998) or De León's (1999a, 1999b, 2001) spontaneous speech findings. On balance, the data regarding a Tseltal noun bias are then somewhat mixed: evidence against a noun bias comes from spontaneous speech analyses and evidence in favor of it comes from the checklist data; meanwhile evidence for facilitated early verb learning appears consistent across these datasets.

Relative representation with transcription data

Past work on the noun bias in Mayan languages has focused primarily on spontaneous speech data and, therefore, has used measures of proportional frequency (e.g. the proportion of noun types and noun–verb ratio). It would be ideal to instead analyze under- and over-representation, but that approach has only been taken with checklist data. This relative representation approach is ideal because it is the only one that clearly establishes what unbiased development would look like before checking for the presence of a learning bias (E. Bates et al., 1994, 1995; Braginsky et al., 2019; Frank et al., 2021). Importantly, this choice of analysis can enormously impact what we learn from our dataset. Consider, for example, a child who is reported by their parents to say 10 nouns (out of a list of 100) and 5 verbs (out of a list of 50): the child is at 10% in acquiring each word class (i.e. equal relative representations), but the proportional analysis shows very strong noun predominance (a ratio of 2:1, i.e. a strong noun bias). The discrepancy comes from the difference in baseline inventory size, because there are simply many more nouns to learn than verbs.

The logic of the relative representation analysis is something like the following: If we assume that children acquire some core of vocabulary by some age (e.g. that represented by the CDI by age 30 months), unbiased learning would look like uniform, incremental acquisition within and across word classes that reaches 100% at the end of the age range represented. For example, the step from 0% to 10% would happen in parallel across all word classes, regardless of whether 10% represents 100 words or 50

for a given class. That would be unbiased learning – so biased learning would then be whenever learning significantly deviates from this unbiased trajectory. That is, biased learning would happen when children either know proportionally fewer words in a class relative to their overall vocabulary size (i.e. underrepresentation) or proportionally more (i.e. overrepresentation).

Unfortunately, there is no validated vocabulary checklist yet for Tseltal (see Brown et al., 2005, for a preliminary version and Casillas (in preparation) for a checklist in development), but we argue that a similar analysis of relative representation can be undertaken with a large sample of transcript data. In order to conceptually approximate the relative representation analysis with transcript data, we must first establish a core vocabulary that we expect children of a certain age to have acquired. We must then observe which of those words children use within each category, in an age range that starts before the first words are acquired until the last age represented. Rather than a maximal vocabulary list (e.g. the multidialectal Tseltal dictionary; Polian, 2020) we need something akin to a core vocabulary – a list of words known by nearly all Tseltal speakers of the studied geolect.

Conversational talk in everyday life is a reasonable source for vocabulary known by most community members. It is the core ecological niche for languages (unlike, e.g. literacy) – it is the only recognized universal mode of language use and provides the basic context for child language development (Levinson, 2019). Conversational talk also depends on communal common ground, information that community members can mutually assume others have access to (including vocabulary and common experiences; H. H. Clark, 1996, Ch. 4). Even better, conversational talk produced *for* and *by* children gives a closer impression of the words children may be expected to know. To estimate a core vocabulary, we therefore have several choices: words used in talk produced by children, talk directed to children, or both. In what follows we use talk produced by children because it is our best direct evidence of what vocabulary we can expect them to use at the ages observed. That said, we are uncertain which of these options is conceptually optimal for present purposes, so we also provide analyses (with qualitatively identical results) based on target-child-produced *and* target-child-directed speech in the Supplementary Materials.

Defined this way, we gain an analytical framework with similar conceptual value to that set out by Bates, Braginsky, and Frank in their analyses of vocabulary checklist data (E. Bates et al., 1994, 1995; Braginsky et al., 2019; Frank et al., 2021): we create a list of words that children may be expected to say in everyday life by age 52 months, and then we examine which words they actually do say, across an age range spanning from 9 to 52 months. We expect that many of these words would be on a Tseltal equivalent of a CDI, and that children learn many of them by the oldest age we observe. That said, transcription data are highly sparse by nature and children will only demonstrate a small fraction of the words they know in the 45 recording minutes sampled. So, we do not expect within-category word use to reach 100%, which is what we would expect from an age-normed questionnaire like the CDI. What we can do instead is examine over- and under-representation in the developmental space that we are able to observe, where the basic principles of over- and under-representation still hold: unbiased learning would still appear as lock-step relative growth across word classes.

Importantly, we do not yet know how much data are required for such an analysis to be robust. The larger the dataset and the denser the sampling per child, the more that transcript data are likely to approach checklist-like patterns in analysis (Gentner, 1982, 2006 makes a similar argument regarding 'cumulative vocabulary'). The present study is a preliminary attempt to use this analytical approach with the largest existing transcription collection of everyday Tseltal speech (Casillas, 2023). We pair this highly novel approach with a more traditional one – proportional frequency – to holistically examine evidence for a noun bias in Tseltal vocabulary development.

The current study

We analyze the use of noun and verb stems in the spontaneous speech of 29 Tseltal children between ages 0;9 and 4;4 during the course of waking days at home. We first examine proportional frequency of their noun and verb uses to draw direct comparisons to these same estimates from prior work. We then reexamine the same data using a relative representation approach, for which we have no direct prior comparison. The transcript data used here are drawn from a larger, ongoing study of early language development in Tseltal (Casillas, 2023). Based on the work summarized above, we predicted an attenuated noun bias in Tseltal with evidence for early verb learning.

Methods

Participants and community of study

These data come from a collection of recordings made in 2015 of Tseltal Mayan children under age 5;0 (Casillas, Brown, et al., 2017). The collection contains transcribed segments from a cross-sectional sample of 41 recordings of children aged 4;4 and younger (range = 2–52 months; $M = 21.56$ months; median = 19 months). In the analyses we will only use data from the 29 children's recordings at ages 9 months and older (see Figure 2 for data points displaying individual ages). All the children in this sample come from a single rural village in central Chiapas. In this community, Tseltal is the primary language spoken (Tenejapan geolect) and subsistence farming is the primary occupation of most adult residents. That said, many families have one adult who earns income by some other means (e.g. via driving a taxi, extra-community labor, etc.). All children in the sample were growing up speaking Tseltal as their primary home language, though most also heard Spanish spoken regularly in public (e.g. near the school grounds), in some overhearable adult speech, in radio and television programs, and in the borrowing of Spanish words into Tseltal (e.g. *karo*/*carro* for car). Children in this sample were too young to attend school services and so typically spent their days in the company of family members, often at home (but not always; e.g. passing hours at a family garden plot, visiting others' homes, on an errand, etc.).

In this community, infants aged <1 spend most of the day in a sling worn by their mother, or sometimes another close female relative, where they can be quickly and easily repositioned for sleeping (back), feeding (front), and observing the ongoings around them (hip/back) while the person carrying them engages in her daily tasks. Later in

development, between ages 3 and 5, children begin to spend significantly more time in the company of other children, typically siblings, cousins, and other neighbors. Most housing is organized patrilocally such that children are raised in the close vicinity of their father's parents and his brothers' families. In our database, the typical inter-child interval is around 3 years and the typical household size is 7 people including the target child (household members is defined here as number of people sharing a kitchen or other primary living space; range = 3–15). For this reason, we can expect that the typical daily language experience of an infant in the dataset is rather different from that of an older toddler, a difference which is reflected in input rate fluctuations over the day (Casillas et al., 2020). Summing up, Tseltal is these children's primary source of linguistic input, this input comes primarily from family members and, increasingly with age, comes from other children.

Recording procedure

Participants were recruited by word of mouth over the course of approximately 4 weeks by a local member of the community who worked with author M.C.. Consent was conducted verbally and iteratively, exclusively in Tseltal: at the point of initial recruitment, the local research assistant described the recording task and compensation plan, including what is captured on the recording device and any information about the visiting researcher that the participant was curious about; then before the planned recording day, the research assistant reminded the participating family about the task and what would be captured on the recording device – family members who did not want to be recorded were notified so that they could go elsewhere on the recording day; before the start of recording, a more formalized consent process was conducted, going over the task, compensation, participant rights, and the future use of the recording data. Participants were able to ask questions and check understanding at each point of consent. On the recording day, the research assistant and M.C. visited the participating family to collect demographic information about the target child and their family via interview before initiating the recording.

Once oral consent was given (not typically recorded), the research assistant approached the target child and fitted them with a harness that included an already-live audio recorder (Olympus WS-832) and chest camera that took photos every 30 seconds (Narrative Clip 1 + Photojojo Super Fisheye lens). Then the research assistant demonstrated how to use the privacy flap of the harness, a cover for the lens that could be quickly attached/detached in case the participants wanted to temporarily block the camera's view. Caregivers were encouraged to use the cover if they wanted privacy, but to otherwise try and leave the lens uncovered. Caregivers were asked to temporarily take the harness off the child if it was disturbing their sleep or if the child was going to get excessively wet, and in those cases to just place it near to the child. The intention of a daylong recording is to get an estimate of children's typical at-home language input. In reality, the recording day is still a *special* day in which certain family members may have elected not to be present and during which the harness served as a continuous visual reminder that the child's frontal view and proximal auditory environment were being documented. The recorder and camera were commented on frequently throughout the recording day in many children's recordings.

In this 2015 recording collection, a total of 57 recordings were made from 55 children born to 43 mothers (make-up recordings were made in the case of camera/audio recorder failure on the first recording). Recordings typically lasted from mid-morning until sunset, with a mean duration of 8.96 hours of audio recording data (range = 3.0–10.2) and a typical start time of 08:30 (range = 07:18–10:02). Raw audio and photo streams were manually aligned and digitally combined into MP4 video files in 2016.

Data sampling and annotation

Following Casillas and colleagues (2020, 2021), we examine spontaneous speech produced in nine 5-minute clips that were randomly selected from the span of each recording (i.e. 45 total minutes per recording). Clips were nonoverlapping and were selected regardless of ongoing activity (e.g. the child could be sleeping during a clip) to get a fully representative view of language activity during the daytime hours.

Casillas and colleagues (2020) transcribed their clips using the ACLEW Annotation Scheme, which annotates *all* hearable speech on the audio recording with indicators for intended addressee and child vocal maturity (Bunce et al., 2020; Casillas, Bergelson, et al., 2017; Soderstrom et al., 2021). We aimed here for a much larger sample of language data, and so created a minimized adaptation of their annotation scheme that includes transcriptions of all target-child-produced vocalizations (CHI) and all target-child-directed vocalizations (OTR) that appear in the clips. A primary difference in the annotation workflow is then that the present data are limited exclusively to target-child-directed input.

Prior work shows that these Tseltal children encounter a great deal more language input beyond what we can analyze here – other-directed input (e.g. speech between adults or directed to other children) outpaces target-child-directed input at a ratio of 6:1 (Casillas et al., 2020). Our choice to only transcribe target-child-directed input therefore limits any analyses to just a slice of what children may learn from in their linguistic environments, a limitation that could be more impactful for the older children than the younger ones (e.g. Akhtar, 2005; Arunachalam, 2013). As we argue above, however, target-child-produced and target-child-directed speech are the most likely relevant sources of vocabulary for the present analyses. This same decision also allows us to feasibly examine data from more children. Full annotation and transcription of all hearable speech for Tseltal daylong recordings requires two annotators (a native speaker and an expert in ELAN) and takes approximately 50 minutes of work for every 1 minute of recorded audio (Casillas et al., 2020). By reducing our transcription and annotation goal to target-child-produced and target-child-directed speech, the task speeds up immensely, becoming possible year-round as a project led by a single native speaker of Tseltal. Even so, the transcription data analyzed here represent more than 2 years of focused work.

For present purposes, the transcribed utterance annotations were supplemented as follows: loose translations of each utterance into Spanish (tlsp), an indication of speaker type for all speech directed to the target child (quien; e.g. woman/man/girl/boy/other), and a list of each noun (sus) and verb (ver) stem used in each utterance (see Figure 1).

All transcription, translation, and noun and verb annotation was completed by author J.M.G., a native speaker of Tenejapan Tseltal who resides outside of the village studied.

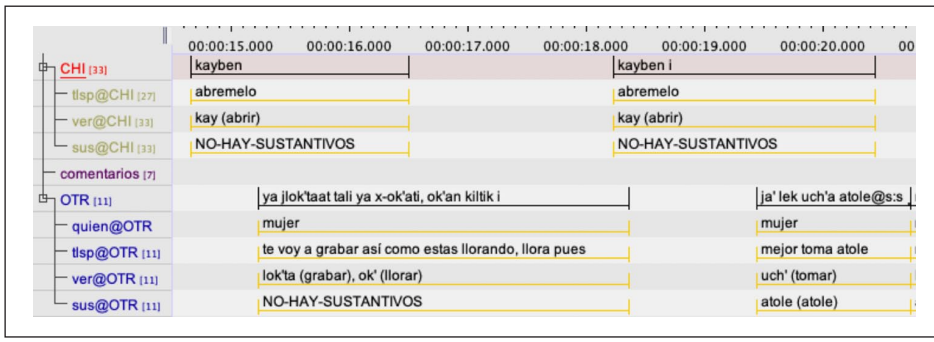

Figure 1. Screenshot of Approximately 5 Seconds from One Transcript File Showing the Hierarchical Tier Structure Used to Organize Transcription, Translation, and Noun and Verb Annotation. Linked Media for Each Clip Included a .wav Audio File and an .mp4 Video File Showing Time-Aligned Child-Worn Chest cam Photos When Possible.

All transcription and annotation were done in the video annotation software ELAN (Wittenburg et al., 2006). Of the original 57 recordings in the 2015 collection, we here include the 29 to which this annotation pipeline applies and for which the target child is 9 months old or older (range = 9–52 months; $M = 28.44$; median = 29; $SD = 12.86$). We use 9 months as our starting point because it is likely to conservatively capture the onset of first word productions, which we would typically expect to occur around 12 months (Casillas et al., 2020; Schneider et al., 2015). We do *not* analyze the 10 additional recordings processed using the ACLEW Annotation Scheme by Casillas and colleagues (2020) given the significant differences between their and our annotation workflow and annotation team (J.M.G. vs. a village-local research assistant who knew all the families).

While we believe the transcriptions and annotations to be overall of a very high quality, we note that this corpus is a living resource that serves multiple research projects simultaneously. We expect to gradually add annotations for other types of language input, other linguistic features of produced speech, and small corrections to segmentation and transcription over the decades to come. Thus the data in this article should be taken as a snapshot from a living and growing resource. Ultimately, we plan to replicate and extend these analyses with the full audio recording ($N = 57$) dataset and with a validated Tseltal vocabulary checklist.

Data preparation

To prepare the transcripts for analysis, we used the phonfieldwork library in R (Moroz, 2021) to convert the transcribed data from .eaf files into a tabular format. We then created tabular summaries of noun and verb use using the tidyverse library (Wickham et al., 2019). Verb and noun stems were then exported and manually annotated by author M.C. to match the standardized forms and metadata from the open online Tseltal–Spanish multidialectal dictionary (Polian, 2020). This manual annotation step is necessary given the current lack of an automatic stemming program for Tseltal and variability in

orthographic forms. In this manual annotation process, author P.B. also provided further metadata on verb classification to inform the final analyses. Nouns were considered to include all instances of noun, action noun, phrasal nouns, and proper nouns. Note that kin terms were not separately classified when used vocatively (i.e. when used like proper nouns, 'Mommy, come!' vs. 'That's my mommy') – we here treat all kin term uses as if they were instances of basic nouns. Verbs were considered to include all instances of agentive intransitive verbs, defective intransitive verbs, movement intransitive verbs, phrasal intransitive verbs, intransitive verbs, defective transitive verbs, transitive verbs, and auxiliaries. These standardized word classes were derived from the open online Tseltal-Spanish multidialectal dictionary (Polian, 2020). These manually checked data were then read back into R for statistical analysis. Our analyses of over- and under-representation are based on R code openly available from the WordBank book (Braginsky et al., 2019; Frank et al., 2021). All plots are created with the ggplot library (Wickham, 2016) and statistical analyses are run with the lme4 library (D. Bates et al., 2015). A reproducible version of this manuscript was created using the papaja and Rmarkdown libraries in the desktop application Rstudio (Aust & Barth, 2022), which is available with anonymized data on an Open Science Foundation repository (https://osf.io/9gmzr/).

Results

In what follows, we will first give an overview of the noun and verb data available in the corpus. We then review the findings given the traditional, proportional frequency approach, making direct comparisons to past work. After that, we review the findings again, this time using the more recent, relative representation approach, which is adapted here for transcription data.

The dataset includes 11,485 vocalizations: 9011 produced by the target child, 1677 produced by an adult, and 797 produced by another child. Of these, 2919 utterances contained at least one noun or verb: 1811 of the target child's utterances (20.1%), 784 of the adult utterances (46.7%), and 317 of the other children's utterances (39.8%; see the Supplementary Materials for an analysis using these target-child-directed speech stems).

Among the 29 target children, 28 produced at least one noun or verb in the 45 observed minutes; all children older than 1 year were observed to produce a noun or a verb (range: 1–170). The youngest age at which a child-produced noun stem was recorded at 10 months (*chenek'* 'bean' and *mamá* 'mom') and the youngest age at which a child-produced verb was recorded at 9 months (*ich'* 'take/hold'; *ak'* 'give/put' came second, with a production at 10 months). These first noun and verb stems fall well in line with prior work positing that kin terms are among the very first words observed in production (e.g. Brown, 1998; De León, 1999a, 1999b, 2001; Gentner, 1982, 2006; Schneider et al., 2015) while these early uses of general 'light' verbs stand in contrast to prior Tseltal findings from Brown (1998).

Proportional frequency measures

We first examine the proportional frequency values in the present dataset, then compare them to past work on Mayan languages, then to those from past work on other languages. By-child estimates of noun and verb stem use in child-produced speech are summarized

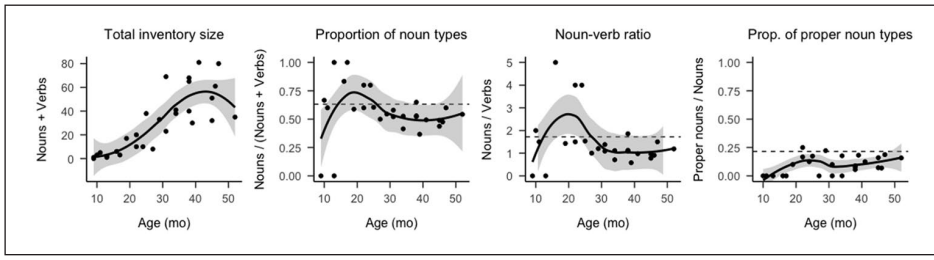

Figure 2. Raw Inventory Measures of Child-Produced Noun and Verb Stems Plotted by Child Age, Including: Total Noun-Verb Stem Inventory Size (Left), Proportion of Unique Stems that are Nouns (Center-Left), Ratio of Unique Noun Stems to Unique Verb Stems (Center-Right), and Proportion of Unique Noun Stems that are Proper Nouns (Right). Estimates of Each Measure from the Total Pool of Observed Unique Noun and Verb Stems (i.e. Across All Target-Child-Produced and All Target-Child-Directed Speech) are Shown as Dashed Horizontal Lines, Except Total Inventory Size (NB: The Total Pooled Inventory is 386 Unique Noun and Verb Stems). Thick Black Lines Indicate a Smoothed Fit Using the loess() Function from the ggplot Library in R (Wickham, 2016) for Which the Shaded Regions Indicate Estimated 95% Confidence Intervals.

in Figure 2, and average values for these data and comparable past datasets are summarized in Table 2.

Collectively, the children produced 248 noun types and 138 verb types. The total noun and verb stems (i.e. vocabulary size) observed for each child increased with age (Figure 2, leftmost panel) The proportion of noun types in individual children's inventories averaged 0.56 (range: 0.0–1.0; two children with very small inventories produced only verbs; Figure 2, center-left panel) and the ratio of nouns to verbs averaged 1.48 (range: 0–5; two children with very small inventories produced only nouns; Figure 2, center-right panel). If we consider a noun bias to be any proportion of nouns over 0.5, 19 of the 28 children who produced one or more nouns or verbs showed a noun bias (67.9%). If we consider a noun bias to be any noun-verb ratio over 1.0, again 19 of the 28 children who produced one or more nouns or verbs showed a noun bias (67.9%).

The noun bias is predicted to be most apparent in the earliest period of word production (especially within the first 50–100 words; Gentner, 2006), which cross-linguistic data suggest may be typically reached between 16 and 20 months (Frank et al., 2021: Chapter 5.1). We therefore conducted *t*-tests on our data comparing proportion of noun types and noun-verb ratio before and after 20 months of age. We found no evidence for a difference between early (⩽20 months) and later (21+ months) noun bias measures among children who produced at least one noun or verb (proportion of noun types: $t(7.429) = 0.253$, $p = 0.807$, 95% CI = [−0.296, 0.368]; noun-verb ratio: $t(5.79) = 0.296$, $p = 0.778$, 95% CI = [−1.690, 2.151]). A close examination of Figure 2 makes evident that, at the earliest ages documented, children exhibited dramatic variation in their proportional noun use, with two children categorically using nouns and two children categorically using verbs.

How do these findings compare with past work? Age and data preprocessing differences aside, the outcomes are comparable – if not very slightly more favorable to a noun bias – compared with past work on Mayan languages (Brown, 1998; Brown

Table 1. Examples of three child-produced utterances in the dataset, including a gloss for each and the nouns and verbs extracted from each for the present analysis.

Complete child utterance and gloss	Nouns	Verbs
stsek alal *s-tsek alal* 3POSS-skirt baby 'the baby's skirt'	tsek (wrap skirt), alal (baby)	NA
jtsaktik jilel ku'untik eki *j-tsak-tik jilel k-u'un-tik ek=i* 1ERG-take-PL DIR 1POSS-REL.N-PL also=PART 'we keep ours too'	NA	tsak (take/ hold)
uk'um jpastik *uk'um j-pas-tik* river 1ERG-do-PL 'we do it (at) the river'	uk'um (river)	pas (do/ make)

Glossing abbreviations as follows: DIR: directional; ERG: ergative; PART: particle; PL: plural; POSS: possessive; REL.N: relational noun.

et al., 2005; De León, 1999b; Table 2). In work using spontaneous speech, Mayan language researchers have preferred to count proper nouns and kin terms separately from the basic noun category (reasoning differently from Gentner's, 1982, 2006 studies), which consequently yields lower overall noun proportions. If we count proper nouns as basic nouns (Table 2), our current outcomes appear more favorable to a noun bias than previously reported: Brown's (1998) Tseltal data showed a 0.53 proportion of noun types and a 1.17 noun–verb ratio ($\Delta = -0.03$ and -0.31 from the present data) and De León's (1999b) Tsotsil data showed a 0.46 proportion and 0.85 ratio ($\Delta = -0.10$ and -0.63 from the present data). The present outcomes are more comparable to data from the preliminary Tseltal vocabulary checklist (Brown et al., 2005): a 0.57 proportion of noun types and a 1.34 noun–verb ratio ($\Delta = +0.01$ and -0.14 from the present data), though proportion of noun types in that study is calculated over total vocabulary size (i.e. including an 'other' category) and so is somewhat underestimated relative to our present calculation.

We can also roughly compare the present outcomes to those reported in Gentner's (1982) foundational study of Mandarin, Japanese, Kaluli, German, English, and Turkish ($N = 2$–4 children per language). In that paper, verbs are subsumed under the category of predicates (which includes verbs, prepositions, and modifiers), such that her verb-related outcomes will appear more generous than ours (i.e. verbs only). Nonetheless, we see that the Mayan outcomes, in the present work and in past studies, are less favorable to a noun bias than what was reported for these six other languages (derived from Gentner's, 1982, Table 4): a cross-linguistic range of 0.68–0.85 in proportion of noun types ($\Delta = +0.12$–0.29 from the present data) and a range of 2.3–6.17 in noun–predicate ratio ($\Delta = +0.82$–4.69 from the present noun–verb ratio data). As a reminder, Gentner's (1982) data use a 'predicate' category rather than a 'verb' category, and so if we could calculate the

Table 2. Overview of proportional frequency estimates reported in this study and in prior studies of Mayan noun and verb development (Brown, 1998; De León, 1999b).

Study	Sample characteristics	Proportion of noun types $\frac{\#Types_N}{\#Types_{N+V}}$	Noun–verb ratio $\frac{\#Types_N}{\#Types_V}$	Proportion of proper noun types $\frac{\#Types_{PropN}}{\#Types_N}$	Notes
This study	• Language: Tenejapan Tseltal • *N* = 29 (9–52 mo) • Source: Cross-sectional daylong audio recordings; 9 × 5-minute randomly sampled clips	0.56	1.48	0.096	• Based on children who were observed to produce at least one noun or verb • Kin terms treated as basic nouns
Gentner (1982)	• Language: Mandarin, Japanese, Kaluli, English, German, and Turkish • *N* = 16 (N = 2–4 per language; 14–29 mo) • Source: English-glossed transcripts of home recordings (Kaluli, Mandarin, Turkish) or caregiver-elicited cumulative vocabulary (all others; see Gentner, 1982, Appendix A)	0.68–0.85[a] Kaluli: 0.68 Mandarin: 0.70 Turkish: 0.74 Japanese: 0.79 English: 0.82 German: 0.85	2.3–6.17[b] Kaluli: 2.30 Mandarin: 2.31 German: 2.44 Turkish: 3.10 Japanese: 4.33 English: 6.17	0.15–0.88 English: 0.15 German: 0.18 Turkish: 0.29 Japanese: 0.36 Mandarin: 0.41 Kaluli: 0.88	• [a]Based on that paper's Table 4; instead of unique verb types these calculations use unique predicate types, which include verbs, prepositions, and modifiers • [b]Based on that paper's Table 5; only includes first-words data from one child per language
Brown et al. (2005)	• Language: Tenejapan Tseltal • *N* = 5 ('young children'; age not reported) • Source: Caregiver-report in a Tseltal vocabulary checklist with 594 words (283 nouns, 207 verbs, 104 other words)	0.57[c]	1.34	0.30	• [c]This proportion is calculated over total vocabulary size (not just Ns + Vs) and so is likely underestimated relative to the other values in its column

(Continued)

Table 2. (Continued)

Study	Sample characteristics	Proportion of noun types $\frac{\#Types_N}{\#Types_{N+V}}$	Noun–verb ratio $\frac{\#Types_N}{\#Types_V}$	Proportion of proper noun types $\frac{\#Types_{PropN}}{\#Types_N}$	Notes
Brown (1998)	• Language: Tenejapan Tseltal • *N* = 2 (15–29 mo) • Source: Monthly longitudinal home audio recordings with occasional home video recordings	0.53	1.17	0.16	• Based on that paper's Table 1, treating proper Ns as Ns and excluding 'Other' • Averaged estimates across MLU stages and children
De León (1999b)	• Language: Zinacantán Tsotsil • *N* = 2 (20–25 mo) • Source: Weekly or biweekly longitudinal home audio or video recordings from extended family visits during the sample period	0.46	0.85	0.12	• Based on that paper's Table 3, treating proper Ns and kin terms (reported jointly with proper Ns) as Ns and excluding all other categories

The two comparable measures include: (A) Proportion of Noun Types (here defined as the number of unique noun types divided by the sum of the number of unique noun types and number of unique verb types); (B) the Noun-Verb Ratio (here defined as the number of unique noun types divided by the number of unique verb types); and (C) the Proportion of Proper Noun Types (here defined as the number of unique proper noun types divided by the number of all unique noun types). In (A) and (B), 'noun types' include proper nouns, though we note this is an important point of contention between the studies cited. In the example equations above, 'N' = all nouns (including proper nouns), 'V' = all verbs, and 'PropN' = nouns sub-classified as proper nouns.

proportion and ratio with only verbs it would likely show an even stronger noun bias in these six languages compared with the Mayan datasets.

An essential subcomponent of the noun bias debate centers specifically on the early presence of proper nouns, so we briefly compare these proportional data as well. Collectively, the children in our dataset produced 248 noun types, of which 44 were classified as proper nouns (Figure 2, rightmost panel). Notably, these 44 proper nouns include form variations on a subset of the proper names observed (e.g. 'Manuel', 'Manel', and 'Man' as variations on the name *Manel*); the 44 proper noun forms are based on approximately 32 unique person names. Among the children who produced one or more noun stems, the mean proportion of nouns that were proper nouns was 0.096 (range: 0.00–0.25). This is lower than what has been reported across all prior studies. It is most comparable to prior analyses of Mayan children's spontaneous speech data, Tseltal (Brown, 1998): 0.16, $\Delta = +0.064$; and Tsotsil (De León, 1999b): 0.12, $\Delta = +0.024$, but much lower than the checklist-based estimate for Tseltal (Brown et al., 2005; 0.30, $\Delta = +0.204$) and lower than the range of values reported for all six languages examined in Gentner (1982: 0.15–0.88, $\Delta = +0.054$–0.694).

Relative representation

As explained above, the drawback of using the proportion of noun types or the noun–verb ratio as primary measures of a noun bias is that they do not take into account the baseline prevalence of nouns and verbs, and so cannot directly speak to over- or under-representation. In contrast, the more novel 'relative representation' approach clearly defines unbiased learning and thereby provides a path for examining *biased* learning trajectories. As explained above, this analytical approach originates with E. Bates et al. (1994, 1995) and was recently popularized by Braginsky and colleagues (2019; Frank et al., 2021) who have used it to confirm a consistent overrepresentation of nouns and underrepresentation of predicates (including verbs) in the productive vocabulary checklist data from 27 languages. While relative representation has not previously been used with transcription data, we argue above that it can be conceptually approximated given sufficient transcription data, with the caveat that we do not expect within-category learning to reach anywhere near 100% – even at the oldest ages in our sample – given the sparsity of observed stems in spontaneous speech.

Across the entire dataset of target-child-produced speech,[3] we observed 248 unique noun stems and 138 unique verb stems, giving us a total stem inventory size of 386. These 386 stems make up our core vocabulary, against which we compare individual children's observed noun and verb stem uses. To illustrate the scoring process, we give a concrete example from a 19-month-old female child: she was observed to use 10 unique noun stems and 7 unique verb stems, so her total relative inventory size is 0.044, total child inventory divided by total core inventory; (10 + 7/386), her relative noun inventory size is 0.040 (total child noun inventory divided by total core noun inventory; 10/248), and her relative verb inventory size is 0.051 (total child verb inventory divided by total core verb inventory; 7/138). Using this process, we calculated a total relative inventory size, a relative noun inventory size, and a relative verb inventory size for each child in the dataset.

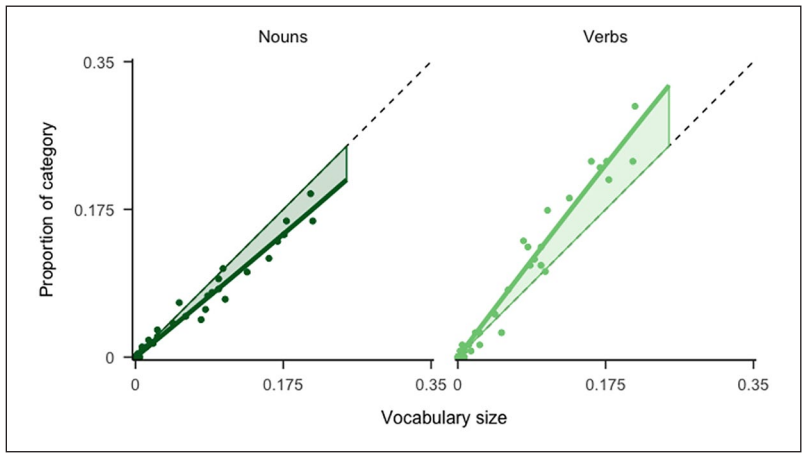

Figure 3. Relative Representation of Nouns (Left) and Verbs (Right): Proportion of Stems Acquired for the Given Category Plotted Against the Proportion of Stems Acquired for the Total Noun and Verb Stem Inventory. Each Data Point Represents an Individual Child, and the Thick Line Shows the Constrained Model Fit, with the Shaded Regions Highlighting the Estimated Area between the Expected Unbiased Developmental Trajectory (The Diagonal Line) and the Actual Observed Data (The Data Points) in the Range of Vocabulary Sizes Observed (Total Relative Vocabulary Size = [0.00:0.21]).

Following Braginsky and colleagues (2019; Frank et al., 2021), for each syntactic type, we fit a constrained linear model of relative representation predicting the proportion of types acquired within a word class (*y*-axis in Figure 3) by the proportion of types acquired across the total vocabulary (*x*-axis in Figure 3). As in prior work, our models included third-order polynomials to allow for a variety of concave or convex fits and were constrained to predict that children will have acquired 100% of the category when they have acquired 100% of the total vocabulary[4] – a constraint that still holds even if we expect to only see a fraction of the developmental trajectory between 0% and 100%. As expected, the observed stems used were sparse compared with the core vocabulary pool: the child with the largest total vocabulary had only acquired 0.21 of the total observed noun and verb stem inventory. Thus, our full dataset resides in the bottom-left corner of the constrained fit from (0,0) to (1,1) and we examine under- and over-representation in this early portion of the developmental trajectory. We note that the limited observed range conservatively biases against finding a consistent difference from unbiased learning, given that the model fits the full range between 0% and 100% learning.

Within the 29 individual children, 21 children (72.4%) show noun underrepresentation (i.e. under the diagonal; $M = -0.01$) and 21 children (72.4%) show verb overrepresentation (i.e. over the diagonal; $M = 0.02$). These 21 children perfectly overlap, showing both noun underrepresentation and verb overrepresentation. Among the remaining 8 children, 7 show the reverse (i.e. NP/RR hypothesized) pattern, though with a much smaller effect: noun overrepresentation ($M < 0.001$) and verb underrepresentation ($M = -0.01$). One child had no observed noun or verb stems in their recording, and so is

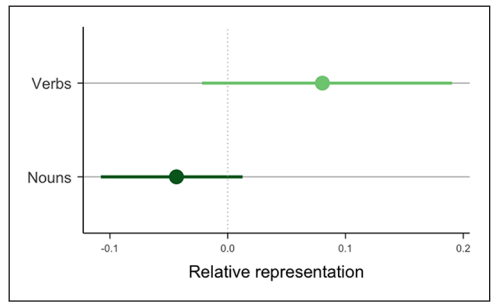

Figure 4. Relative Representation Effect Estimates for Nouns and Verbs, with Horizontal Thick Lines Showing the Bootstrapped 95% Confidence Intervals for Each Class.

at 0 on all measures (Figure 3). These numerical trends, while consistent, have weak inferential value on their own. What we need to complement them are bootstrapped estimates of the area over and under the diagonal across our sample to test whether what we have observed is likely to be different from chance.

We again followed Braginsky and colleagues (2019; Frank et al., 2021) in generating confidence intervals of the difference from unbiased learning in the interval from 0% to 100% vocabulary size (Figure 4) by randomly sampling the data 1000 times with replacement and then fitting the same model for each random sample to measure the area of apparent bias. These area estimates were then used to generate upper and lower confidence intervals of a difference from no bias (i.e. an area of 0). In lay terms, distributions with confidence intervals that largely overlap the zero estimate are more consistent with a lack of bias; values below zero indicate underrepresentation and values above zero indicate overrepresentation.

While the numerical estimates of the bootstrapped confidence intervals remain the same as the whole-dataset analysis above (i.e. negative for nouns and positive for verbs), the substantial overlap with zero in both distributions suggests no significant evidence for biased noun or verb learning (*M* area for nouns: −0.043, 95% CI = [−0.10 8, 0.013]; verbs: 0.080, 95% CI = [−0.022, 0.191]; Figure 4). We do note that the relative representation estimate effect sizes from these data (nouns: −0.043; verbs: 0.080) are comparable to statistically significant cases of over- and under-representation found in Braginsky and colleagues (2019; Frank et al., 2021); however, in our smaller and noisier dataset, the estimated uncertainty is higher, especially given that we have no observed data for the vocabulary size interval between 0.21 and 1.0.

Discussion

Early language development is driven forward in part by the cognitive biases that children bring to the process of learning. A great deal of evidence – observational, experimental, and checklist-based – suggests that concrete objects have a perceptual and conceptual advantage in early word learning compared with relations, a vocabulary development pattern known as the ‘noun bias’. In this article we have examined the noun

bias hypothesis in Tseltal-acquiring children. We were interested to study Tseltal vocabulary development in particular because grammatical properties of the Tseltal language and communicative practices in Tseltal child–caregiver interaction heighten the conceptual salience of verbs while dampening the conceptual salience of nouns. Prior work investigating a noun bias in Tseltal had appeared mixed, with one result in favor of the bias (Brown et al., 2005; Gentner, 2006; checklist data) and one against (Brown, 1998; spontaneous speech), both using small samples but the latter using in-depth longitudinal observation (see also closely related work from De León, 1999a, 1999b, 2001). Both studies had suggested a cross-linguistically weak noun bias and more robust support for the notion of early and rapid verb learning in Tseltal. The present findings are based on a larger, cross-sectional sample of highly naturalistic Tseltal speech, which we analyze using two approaches: a traditional approach based on proportional frequency measures and a more novel approach examining relative representation within word classes.

Using the more traditional method – proportion of nouns and noun-verb ratio – we indeed found a numerical noun bias in both measures, but the bias was small (i.e. noun proportion: 0.56; noun–verb ratio: 1.48). Comparing as well as possible with past work, our current estimates are similar but slightly more favorable to a noun bias than past work on Mayan languages. Our current estimates are also less noun biased than all six languages reported on in Gentner's (1982) foundational paper. While it is impossible to make an apples-to-apples comparison across these studies, given their variation in sample size, approach, recording context, data pre-processing, and more, the broadly similar values achieved across the three existing Tseltal study samples (noun type proportions of 0.53–0.56; noun–verb ratios of 1.17–1.48) increases our confidence in the presence of small but consistent proportional dominance of nouns over verbs in early Tseltal vocabulary development. This is a pattern that cannot be attributed to method alone (i.e. spontaneous speech vs. checklist). That said, proportional frequency measures do not take into account the baseline quantities of nouns and verbs to be learned and so cannot provide direct insight into unbiased vs. biased learning. For that, we need a measure of relative representation of word classes compared to total vocabulary size, as done previously by Bates, Braginsky, Frank, and colleagues (E. Bates et al., 1994, 1995; Braginsky et al., 2019; Frank et al., 2021).

When we use this more novel method – relative representation – we find no numerical or statistical evidence for noun overrepresentation; we rather see a numerical trend toward verb overrepresentation, a pattern that holds for nearly three-quarters of the individual recordings sampled. In other words, when our measure of biased learning takes into account the size of the noun and verb categories in the lexicon to be acquired, we see no evidence for noun overrepresentation, running counter to the idea of the noun bias. A logically similar analytical approach of relative representation was used recently to show a consistent noun bias in the caregiver-reported productive vocabularies of children learning 27 other languages (Frank et al., 2021), lending credence to the idea that our present results are not just due to the analytical approach. We attempt a novel adaptation of the relative representation approach to transcription data, for which an important practical difference is that only a small fraction of children's productive vocabulary will be observed in the recordings. In our data, the child with the largest inventory used 21% of the total observed noun and verb stems, rather than the nearly 100% of words we might expect for

a normed vocabulary checklist. Our constrained model fits the entire space from 0% to 100%, and so this conservatively works against our ability to statistically evidence a bias, as there is no observed difference from unbiased learning along 80% of the total inventory fit. That said, the individual recording data give a clear glimpse into what we might see with a better estimate of children's cumulative vocabularies: consistent and larger relative underrepresentation for nouns and relative overrepresentation for verbs. These findings would ideally be re-examined in future work that (1) observes a greater amount of data per child to better examine the full spectrum of vocabulary development before 52 months and/or (2) uses a validated vocabulary checklist to test the approach within its original intended analytical context.

Our combined findings suggest that the evidence for a noun bias in Tseltal is very weak – it only appears when baseline inventory sizes are not taken into account and, even then, the bias outcomes are among the lowest reported in the cross-linguistic literature. From the relative representation perspective, the classic noun bias pattern is numerically reversed, appearing instead as a verb bias, though critically the data are too sparse to yield robust statistical inferences about the group-wide pattern. This general lack of strong evidence for a noun bias is expected for Tseltal, given that the grammatical and interactional patterns of Tseltal linguistic input lead to heightened linguistic and conceptual accessibility of verbs and a dampened accessibility of nouns (Brown, 1998; De León, 1999a, 1999b, 2001; Polian, 2013). More broadly, the finding of a very weak noun bias is in line with other cross-linguistic comparative work showing wide variation between languages in the apparent size of the bias (e.g. Au et al., 1994; Braginsky et al., 2019; Choi, 2000; Choi & Gopnik, 1995; Frank et al., 2021; Gentner, 1982, 2006; Gentner & Boroditsky, 2001, 2008; Gopnik & Choi, 1990; Gopnik et al., 1996; Imai et al., 2008; Kim et al., 2000; Setoh et al., 2021; Tardif, 1996; Tardif et al., 1997, 1999, 2008; Xuan & Dollaghan, 2013).

So what then do these findings tell us about the cognitive biases that drive word learning? The NP/RR hypothesis focuses on object nouns (especially animate ones) as optimal exemplars of conceptual accessibility (Gentner, 1982, 2006). Our findings, which follow those of Brown, de León, and others (Brown, 1998; De León, 1999a, 1999b, 2001) suggest an important addition to this story: in-the-moment conceptual accessibility relies not just on intrinsic features of the referent, but also on a number of other critical factors such as linguistic structure, socialization, encultured attention, multimodal signaling, recency, etc.. These factors may play a major role in illuminating intended referents and their intended linguistic labels, giving (perhaps momentary) well-defined conceptual-linguistic mappings of otherwise relatively inaccessible, fuzzy concepts. This same view may help account for the fact that the noun bias is apparently weaker in some linguistic and cultural communities than others (e.g., Frank et al., 2021; Rosemberg et al., 2020; Snedeker et al., 2003; Tardif, 1996): myriad factors may directly or indirectly train children's attention to relevant conceptual categories, in the moment and across instances, preparing them for linguistic labeling.

On this account, we might expect to see accessibility effects that cross syntactic classes, such that – while nouns might have an overall learning advantage – more socio-interactionally, linguistically, and culturally accessible concepts are acquired earlier than others across a variety of different word domains (e.g. concrete and animate vs. abstract

nouns; perceptually salient vs. non-salient concepts encoded in verbs). Indeed, Gentner (1982, 2006) specifically predicts this effect within the category of nouns and others predict it within the category of verbs (Brown, 1998, 2008; E. V. Clark, 1995; Ninio, 1999). Thus, we are here simply proposing to expand the scope and generality of conceptual accessibility advantages to any factor that can significantly heighten momentary accessibility during word learning (i.e. not just inherent conceptual boundedness). Indeed, something akin to these generalized accessibility effects are already captured in the work of Braginsky, Frank, and colleagues (Braginsky et al., 2019; Frank et al., 2021), who find that a word's concreteness and 'babiness' (i.e. strength of baby relevance) are very strong predictors of how early a child is reported to begin producing that word.

Thus, if we had more Tseltal data (spontaneous speech or checklist) we would still expect to see that, for example, within each grammatical category, there would be concreteness effects and, among nouns, earlier acquisition of concrete and animate object words. That is to say, these data may still be partly consistent with the NP/RR hypothesis, but more suggest that object-specific biases should be considered in balance with accessibility factors from the child's linguistic and cultural upbringing that collectively influence the trajectory of early lexical development.

Limitations and future directions

We urge caution in generalizing these findings for several important reasons. First, while this dataset represents an unprecedentedly large sample of Tseltal children's speech (e.g. nearly tripling the sample size in Casillas et al., 2020), the number of participants relative to the age range is still small and the data are cross-sectional (not longitudinal, like the other work on Tseltal and Tsotsil; Brown, 1998, 2009; De León, 1999a, 1999b, 2001). There are also only 45 observed minutes of recording for each child, and the clips were selected randomly, which manifested as a highly limited range of children's observed productive vocabularies. It would be ideal, for example, to zoom in more closely to the speech of children who are at the early stages of lexical production among our wide age sample. We are already planning to conduct denser sampling from these recordings – when ready, these additional data will increase the reliability of our lexicon estimates for each child and, in the process, reduce the uncertainty of our bootstrapped estimates.

Second, the relative representation estimate analysis was originally designed for normed checklist data, and until we can compare our transcript-based estimates with checklist data, our current analyses will remain somewhat experimental. Brown and colleagues (2005) initialized a vocabulary checklist for Tseltal, but it requires further refinement, piloting, and analysis before we can use it with a larger sample of Tseltal children to test relative representation with checklist data (such an effort is underway; Casillas et al., in preparation). In the shorter term, one could address this limitation by replicating the present analyses with noun and verb data from English daylong recordings to see whether we replicate the classic noun bias finding for English (a very strongly biased language; Frank et al., 2021) or whether there is something about relative representation of transcript data that undermines an apparent noun bias. Finally, to fully round out these data, we would also ideally experimentally examine novel word learning (e.g. Childers & Tomasello, 2002; Imai et al., 2008) but in a way that is sensitive to culturally typical

contexts for interactional word learning in Tseltal. For now, we take these findings as an important data point in the noun bias debate and as support for the ethnographically informed perspective on Mayan language acquisition, which has consistently emphasized the strength of early verb learning over early noun learning (Brown, 1997, 1998, 2001, 2007, 2008; Brown et al., 2005; De León, 1999a, 1999b; Pye et al., 2007).

Conclusion

This study examined evidence for a noun bias in the productive vocabularies of 29 Tseltal-acquiring children (9–52 months old) using two analytical approaches: proportional frequency and relative representation. Children learning Tseltal encounter a range of linguistic and socio-interactive features that diminish the salience of nouns while heightening the salience of verbs, motivating the present study. Proportional frequency estimates suggest a consistent, but very small noun bias that is in line with prior work reported on Mayan vocabulary development and smaller than what has been reported for other languages. Relative representation estimates, on the contrary, suggest no noun bias at all, with most children showing numerically flipped data: overrepresentation of verbs and underrepresentation of nouns. Our findings echo past cross-cultural research in this domain: the influence of a referent's inherent conceptual accessibility (à la NP/RR hypothesis) is mediated substantially by linguistic and cultural factors that can cause a weakening (sometimes an apparent reversing) of their predicted effects on early word learning.

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Author contributions

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Supplemental material

Supplemental material for this article is available online. Scripts, anonymized data, and a version of this manuscript in Spanish (with a summary in Tseltal) are provided on OSF: https://osf.io/9gmzr.

Notes

1. Indo-European languages (marked with an asterisk * above) are spoken by nearly half of the world's population but only make up around only 6% of the world's ~7000 languages (Skirgård, 2017; see also Hammarström et al. (2023) and Simons and Fennig (2017) for more). Six of the nine non-Indo-European languages in this list are similarly major languages spoken in large, post-industrial societies. The list diversifies somewhat if we include studies of word *comprehension* (e.g. see Braginsky et al., 2019; Frank et al., 2021).
2. Notably, this interpretation depends on treating proper nouns as a separate category. Gentner (1982; 2006) argues that proper nouns are critical to the analysis of an early noun bias because they likely include the most salient animate objects in children's early environments. If proper nouns are included as nouns, the two children in Brown's (1998) study *do* initially show a noun bias, but the noun inventory is quickly outstripped by verbs.
3. In the Supplementary Materials we give an alternative version of this analysis in which the core vocabulary is based on both target-child-directed and target-child-produced speech; this change in core vocabulary operationalization yields qualitatively similar results. We attribute the similar results to the overall low volume of target-child-directed speech, which only adds 91 noun stems and 59 verb stems to the combined version of core vocabulary (26.80% and 29.90% of the categories, respectively).
4. clm(prop_category ~ I(prop_vocab ^ 3) + I(prop_vocab ^ 2) + vocab − 1).

References

Akhtar, N. (2005). The robustness of learning through overhearing. *Developmental Science*, *8*(2), 199–209. https://doi.org/10.1111/j.1467-7687.2005.00406.x

Arunachalam, S. (2013). Two-year-olds can begin to acquire verb meanings in socially impoverished contexts. *Cognition*, *129*(3), 569–573. https://doi.org/10.1016/j.cognition.2013.08.021

Au, T. K. F., Dapretto, M., & Song, Y. K. (1994). Input vs constraints: Early word acquisition in Korean and English. *Journal of Memory and Language*, *33*(5), 567–582.

Aust, F., & Barth, M. (2022). *papaja: Prepare reproducible APA journal articles with R Markdown* (R Package Version 0.1.1). https://github.com/crsh/papaja

Baillargeon, R. (1993). The object concept revisited: New directions in the investigation of infants' physical knowledge. In C. E. Ganrud (Ed.), *Carnegie Mellon symposia on cognition: Vol. 23. Visual perception and cognition in infancy* (pp. 265–315). Erlbaum. https://doi.org/10.4324/9780203763032

Bassano, D. (2000). Early development of nouns and verbs in French: Exploring the interface between lexicon and grammar. *Journal of Child Language*, *27*(3), 521–559. https://doi.org/10.1017/S0305000900004396

Bates, D., Mächler, M., Bolker, B., & Walker, S. (2015). Fitting linear mixed-effects models using lme4. *Journal of Statistical Software*, *67*(1), 1–48. https://doi.org/10.18637/jss.v067.i01

Bates, E., Dale, P. S., & Thal, D. (1995). Individual differences and their implications for theories of language development. In P. Fletcher, & B. MacWhinney (Eds.), *The handbook of child language* (pp. 95–151). Blackwell. https://doi.org/10.1111/b.9780631203124.1996.00005.x

Bates, E., Marchman, V., Thal, D., Fenson, L., Dale, P., Reznick, J. S., Reilly, J., & Hartung, J. (1994). Developmental and stylistic variation in the composition of early vocabulary. *Journal of Child Language*, *21*, 85–123. https://doi.org/10.1017/S0305000900008680

Bornstein, M. H., Cote, L. R., Maital, S., Painter, K., Park, S. Y., Pascual, L., & Vyt, A. (2004). Cross-linguistic analysis of vocabulary in young children: Spanish, Dutch, French, Hebrew, Italian, Korean, and American English. *Child Development*, *75*(4), 1115–1139.

Braginsky, M., Yurovsky, D., Marchman, V. A., & Frank, M. C. (2019). Consistency and variability in children's word learning across languages. *Open Mind*, *3*, 52–67. https://doi.org/10.1162/opmi_a_00026

Brown, P. (1997). Isolating the CVC root in Tzeltal Mayan: A study of children's first verbs. In E. V. Clark (Ed.), *Proceedings of the 28th annual child language research forum* (pp. 41–52). CSLI/University of Chicago Press.

Brown, P. (1998). Children's first verbs in Tzeltal: Evidence for an early verb category. *Linguistics*, *36*(4), 713–754. https://doi.org/10.1515/ling.1998.36.4.713

Brown, P. (2001). Learning to talk about motion UP and DOWN in Tzeltal: Is there a language-specific bias for verb learning? In M. Bowerman, & S. C. Levinson (Eds.), *Language acquisition and conceptual development* (pp. 512–543). Cambridge University Press. https://doi.org/10.1017/CBO9780511620669

Brown, P. (2007). Culture-specific influences on semantic development acquiring the Tzeltal 'benefactive' construction. In B. Pfeiler (Ed.), *Learning indigenous languages: Child language acquisition in Mesoamerica* (pp. 119–154). Mouton de Gruyter. https://doi.org/10.1515/9783110923148

Brown, P. (2008). Verb specificity and argument realization in Tzeltal child language. In M. Bowerman, & P. Brown (Eds.), *Crosslinguistic perspectives on argument structure: Implications for learnability* (pp. 167–189). Erlbaum.

Brown, P. (2011). The cultural organization of attention. In A. Duranti, E. Ochs, & B. B. Schieffelin (Eds.), *The handbook of language socialization* (pp. 29–55). Wiley-Blackwell. https://doi.org/10.1002/9781444342901

Brown, P. (2014). The interactional context of language learning in Tzeltal. In I. Arnon, M. Casillas, C. Kurumada, & B. Estigarriba (Eds.), *Language in interaction: Studies in honor of Eve V. Clark* (pp. 51–82). Benjamins. https://doi.org/10.1075/tilar.12

Brown, P., Gentner, D., & Braun, K. (2005, July). *Initial acquisition of nouns and verbs in Tzeltal speaking children* [Paper presentation]. Tenth International Congress for the Study of Child Language, Berlin, Germany.

Brown, P., Pfeiler, B., de León, L., & Pye, C. (2013). The acquisition of agreement in four Mayan languages. In E. Bavin, & S. Stoll (Eds.), *The acquisition of ergativity* (pp. 271–306). Benjamins.

Bunce, J. P., Soderstrom, M., Bergelson, E., Rosemberg, C. R., Stein, A., Alam, F., & Casillas, M. (2020, September 2). A cross-cultural examination of young children's everyday language experiences. *PsyArXiv*. https://doi.org/10.31234/osf.io/723pr

Caselli, M. C., Bates, E., Casadio, P., Fenson, J., Fenson, L., Sanderl, L., & Weir, J. (1995). A cross-linguistic study of early lexical development. *Cognitive Development*, *10*(2), 159–199.

Casillas, M. (2023). Project: Investigating the noun bias in early language acquisition. https://doi.org/10.17605/OSF.IO/YNKJD

Casillas, M., Bergelson, E., Warlaumont, A. S., Cristia, A., Soderstrom, M., VanDam, M., & Sloetjes, H. (2017). A new workflow for semi-automatized annotations: Tests with long-form naturalistic recordings of children's language environments. In *Proceedings of interspeech 2017* (pp. 2098–2102). Duke University. https://doi.org/10.21437/Interspeech.2017-1418

Casillas, M., Brown, P., & Levinson, S. C. (2017). *Casillas HomeBank corpus*. https://doi.org/10.21415/T51X12

Casillas, M., Brown, P., & Levinson, S. C. (2020). Early language experience in a Tseltal Mayan village. *Child Development*, *91*(5), 1819–1835. https://doi.org/10.1111/cdev.13349

Casillas, M., Gómez Pérez, H., Foushee, R., Méndez Girón, J., Polian, G., & Brown, P. (in preparation). Tenejapan Tseltal expressive vocabulary checklist. https://osf.io/84tdz

Chang-Song, Y. K. (1997). Early word acquisition in Korean: Evidence for constraints view (I). *Korean Journal of Human Development*, *4*(1), 76–86.

Childers, J. B., Porter, B., Dolan, M., Whitehead, C. B., & McIntyre, K. P. (2020). Does children's visual attention to specific objects affect their verb learning? *First Language*, *40*(1), 21–40. https://doi.org/10.1177/0142723719875575

Childers, J. B., & Tomasello, M. (2002). Two-year-olds learn novel nouns, verbs, and conventional actions from massed or distributed exposures. *Developmental Psychology*, *38*(6), 967–978. https://doi.org/10.1037/0012-1649.38.6.967

Childers, J. B., Warkentin, E., Porter, B. M., Young, M., Lalani, S., & Gopalkrishnan, A. (2022). Preschool children's processing of events during verb learning: Is the focus on people (faces) or their actions (hands)? *Brain Sciences*, *12*(3), Article 344. https://doi.org/10.3390/brainsci12030344

Choi, S. (2000). Caregiver input in English and Korean: Use of nouns and verbs in book-reading and toy-play contexts. *Journal of Child Language*, *27*(1), 69–96. https://doi.org/10.1017/S0305000999004018

Choi, S., & Gopnik, A. (1995). Early acquisition of verbs in Korean: A cross-linguistic study. *Journal of Child Language*, *22*(3), 497–529. https://doi.org/10.1017/S0305000900009934

Clark, E. V. (1995). *The Lexicon in acquisition* (No. 65). Cambridge University Press.

Clark, H. H. (1996). *Using language*. Cambridge University Press.

De León, L. (1999a). Verb roots and caregiver speech in early Tzotzil Mayan acquisition. In B. Box, D. Juravsky, & L. Michaelis (Eds.), *Cognition, discourse, and function* (pp. 99–119). CSLI/University of Chicago Press.

De León, L. (1999b). Verbs in Tzotzil (Mayan) early syntactic development. *International Journal of Bilingualism*, *3*(2/3), 219–240. https://doi.org/10.1177/13670069990030020601

De León, L. (2001). Finding the richest path: The role of language and cognition in the acquisition of verticality in Tzotzil. In M. Bowerman, & S. Levison (Eds.), *Language acquisition and conceptual development* (pp. 544–565). Cambridge University Press.

Fenson, L. (2007). *MacArthur-Bates Communicative Development Inventories*. Paul H. Brookes.

Frank, M. C., Braginsky, M., Yurovsky, D., & Marchman, V. A. (2021). *Variability and Consistency in early language learning: The Wordbank project*. MIT Press.

Gentner, D. (1982). *Why nouns are learned before verbs: Linguistic relativity versus natural partitioning* (Technical Report No. 257). Center for the Study of Reading, National Institute of Education. https://eric.ed.gov/?id=ED219724

Gentner, D. (2006). Why verbs are hard to learn. In K. Hirsh-Pasek, & R. Golinkoff (Eds.), *Action meets word: How children learn verbs* (pp. 544–564). Oxford University Press. https://doi.org/10.1093/acprof:oso/9780195170009.001.0001

Gentner, D., & Boroditsky, L. (2001). Individuation, relativity, and early word learning. In M. Bowerman, & S. C. Levinson (Eds.), *Language acquisition and conceptual development* (pp. 215–256). Cambridge University Press. https://doi.org/10.1017/CBO9780511620669

Gentner, D., & Boroditsky, L. (2008). Early acquisition of nouns and verbs: Evidence from Navajo. In V. C. Mueller Gathercole (Ed.), *Routes to language: Studies in honor of Melissa Bowerman* (pp. 35–68). Psychology Press.

Gleitman, L. (1990). The structural sources of verb meanings. *Language Acquisition*, *1*(1), 3–55. https://doi.org/10.1207/s15327817la0101_2

Gopnik, A., & Choi, S. (1990). Do linguistic differences lead to cognitive differences? A cross-linguistic study of semantic and cognitive development. *First Language*, *10*(30), 199–215. https://doi.org/10.1177/014272379001003002

Gopnik, A., Choi, S., & Baumberger, T. (1996). Cross-linguistic differences in early semantic and cognitive development. *Cognitive Development*, *11*(2), 197–225.

Hammarström, H., Forkel, R., Haspelmath, M., & Bank, S. (2023). *Glottolog 4.8.* Max Planck Institute for Evolutionary Anthropology. https://doi.org/10.5281/zenodo.8131084

Imai, M., Li, L., Haryu, E., Okada, H., Hirsh-Pasek, K., Golinkoff, R. M., & Shigematsu, J. (2008). Novel noun and verb learning in Chinese-, English-, and Japanese-speaking children. *Child Development*, *79*(4), 979–1000. https://doi.org/10.1111/j.1467-8624.2008.01171.x

Jackson-Maldonado, D., Thal, D., Marchman, V., Bates, E., & Gutierrez-Clellen, V. (1993). Early lexical development in Spanish-speaking infants and toddlers. *Journal of Child Language*, *20*(3), 523–549.

Kim, M., McGregor, K., & Thompson, C. (2000). Early lexical development in English- and Korean-speaking children: Language-general and language-specific patterns. *Journal of Child Language*, *27*(2), 225–254. https://doi.org/10.1017/S0305000900004104

Levinson, S. C. (2019). Interactional foundations of language: The interaction engine hypothesis. In P. Hagoort (Ed.), *Human language: From genes and brain to behavior* (pp. 189–200). MIT Press.

Mateo Pedro, P. (2015). *The acquisition of inflection in Q'anjob'al Mayan*. John Benjamins.

Moroz, G. (2021). *phonfieldwork: Linguistic phonetic fieldwork tools* (R Package Version 0.0.11). https://CRAN.R-project.org/package=phonfieldwork

Nelson, K. (1973). Structure and strategy in learning to talk. *Monographs of the Society for Research in Child Development*, *38*(1/2), 1–135. https://doi.org/10.2307/1165788

Ninio, A. (1999). Pathbreaking verbs in syntactic development and the question of prototypical transitivity. *Journal of Child Language*, *26*(3), 619–653. https://doi.org/10.1017/S0305000999003931

Pae, S. (1993). *Early vocabulary in Korean: Are nouns easier to learn than verbs?* [Unpublished doctoral dissertation, University of Kansas].

Pfeiler, B., Bittner, D., Dressler, W., & Kilani-Schoch, M. (2003). Early acquisition of the verbal complex in Yucatec Maya. In D. Bittner, W. U. Dressler, & M. Kilani-Schoch (Eds.), *Development of verb inflection in first language acquisition: A cross-linguistic perspective: Vol. 21. Studies on language acquisition* (pp. 379–399). De Gruyter Mouton. https://doi.org/10.1515/9783110899832

Polian, G. (2013). *Gramática del Tseltal de Oxchuc* [Grammar of Oxchuk Tseltal]. Centro de Investigaciones y Estudios Superiores en Antropología Social.

Polian, G. (2020). Tseltal-Spanish multidialectal dictionary. *Dictionaria*, *10*, 1–8109. https://doi.org/10.5281/zenodo.5526550

Pye, C. (1985). The acquisition of transitivity in Quiche Mayan. *Papers and Reports on Child Language Development*, *24*, 115–122.

Pye, C., Pfeiler, B., De León, L., Brown, P., & Mateo, P. (2007). Roots or edges? Explaining variation in children's early verb forms across five Mayan languages. In B. Pfeiler (Ed.), *Learning indigenous languages: Child language acquisition in Mesoamerica* (pp. 15–46). Mouton de Gruyter. https://doi.org/10.1515/9783110923148

Pye, C., Pfeiler, B., & Pedro, P. M. (2017). Mayan language acquisition. In J. Aissen, N. C. England, & R. Z. Maldonado (Eds.), *The Mayan languages* (pp. 19–42). Routledge.

Rosemberg, C. R., Alam, F., Audisio, C. P., Ramirez, M. L., Garber, L., & Migdalek, M. J. (2020). Nouns and verbs in the linguistic environment of Argentinian toddlers: Socioeconomic and context-related differences. *First Language*, *40*(2), 192–217. https://doi.org/10.1177/0142723719901226

Schieffelin, B. B. (1979). Getting it together: An ethnographic approach to the study of the development of communicative competence. In E. Ochs, & B. B. Schieffelin (Eds.), *Developmental pragmatics* (pp. 73–108). Academic Press.

Schneider, R. M., Yurovsky, D., & Frank, M. C. (2015). Large-scale investigations of variability in children's first words. In D. C. Noelle, R. Dale, A. S. Warlaumont, J. Yoshimi, T. Matlock, C. D. Jennings, & P. P. Maglio (Eds.) *Proceedings of the 37th annual meeting of the cognitive science society* (pp. 2110–2115). Cognitive Science Society.

Setoh, P., Cheng, M., Bornstein, M., & Esposito, G. (2021). Contrasting lexical biases in bilingual English–Mandarin speech: Verb-biased mothers, but noun-biased toddlers. *Journal of Child Language*, *48*(6), 1185–1208. https://doi.org/10.1017/S0305000920000720

Simons, G. F., & Fennig, C. D. (Eds.). (2017). *Ethnologue: Languages of the world* (12th ed.). SIL International. http://www.ethnologue.com

Skirgård, H. (2017). *Humans who read grammars: Half of the world's languages are not Indo-European (but almost half of the population speak an Indo-European language)*. http://humans-who-read-grammars.blogspot.com/2017/03/half-of-worlds-languages-are-not-indo.html

Snedeker, J., Li, P., & Yuan, S. (2003). Cross-cultural differences in the input to early word learning. In *Proceedings of the annual meeting of the cognitive science society* (Vol. 25, pp. 1094–1099). Cognitive Science Society. https://escholarship.org/uc/item/15545365

Soderstrom, M., Casillas, M., Bergelson, E., Rosemberg, C., Alam, F., Warlaumont, A. S., & Bunce, J. (2021). Developing a cross-cultural annotation system and MetaCorpus for studying infants' real-world language experience. *Collabra*, *7*(1), Article 23445. https://doi.org/10.1525/collabra.23445

Soja, N. N., Carey, S., & Spelke, E. S. (1991). Ontological categories guide young children's inductions of word meaning: Object terms and substance terms. *Cognition*, *38*(2), 179–211. https://doi.org/10.1016/0010-0277(91)90051-5

Spelke, E. A. (1985). Perception of unity, persistence, and identity: Thoughts on infants' conception of objects. In J. Mehler, & R. Fox (Eds.), *Neonate cognition: Beyond the blooming buzzing confusion* (pp. 89–114). Erlbaum.

Spelke, E. A. (1990). Principles of object perception. *Cognitive Science*, *14*, 29–56. https://doi.org/10.1016/0364-0213(90)90025-R

Tardif, T. (1996). Nouns are not always learned before verbs: Evidence from Mandarin speakers' early vocabularies. *Developmental Psychology*, *32*(3), 492–504. https://doi.org/10.1037/0012-1649.32.3.492

Tardif, T., Fletcher, P., Liang, W., Zhang, Z., Kaciroti, N., & Marchman, V. A. (2008). Baby's first 10 words. *Developmental Psychology*, *44*(4), 929–938.

Tardif, T., Gelman, S. A., & Xu, F. (1999). Putting the 'noun bias' in context: A comparison of English and Mandarin. *Child Development*, *70*(3), 620–635. https://doi.org/10.1111/1467-8624.00045

Tardif, T., Shatz, M., & Naigles, L. (1997). Caregiver speech and children's use of nouns versus verbs: A comparison of English, Italian, and Mandarin. *Journal of Child Language*, *24*(3), 535–565. https://doi.org/10.1017/S030500099700319X

Waxman, S. R. (1991). Convergences between semantic and conceptual organization in the pre-school years. In J. P. Byrnes, & S. A. Gelman (Eds.) *Perspectives on language and thought: Interrelations in development* (pp. 107–145). Cambridge University Press. https://doi.org/10.1017/CBO9780511983689

Waxman, S. R., & Hall, D. G. (1993). The development of a linkage between count nouns and object categories: Evidence from fifteen- to twenty-month-old infants. *Child Development*, *64*, 1224–1241. https://doi.org/10.1111/j.1467-8624.1993.tb04197.x

Wickham, H. (2016). *ggplot2: Elegant graphics for data analysis*. Springer-Verlag. https://ggplot2.tidyverse.org

Wickham, H., Averick, M., Bryan, J., Chang, W., McGowan, L. D., François, R., Grolemund, G., Hayes, A., Henry, L., Hester, J., Kuhn, M., Pedersen, T. L., Miller, E., Bache, S. M., Müller, K., Ooms, J., Robinson, D., Seidel, D. P., Spinu, V., & Yutani, H. (2019). Welcome to the tidyverse. *Journal of Open Source Software*, *4*(43), Article 1686. https://doi.org/10.21105/joss.01686

Wittenburg, P., Brugman, H., Russel, A., Klassmann, A., & Sloetjes, H. (2006). ELAN: A professional framework for multimodality research. In *5th international conference on language resources and evaluation (LREC 2006)* (pp. 1556–1559). http://hdl.handle.net/11858/00-001M-0000-0013-1E7E-4

Xuan, L., & Dollaghan, C. (2013). Language-specific noun bias: Evidence from bilingual children. *Journal of Child Language*, *40*(5), 1057–1075. https://doi.org/10.1017/S0305000912000529