CHILD DEVELOPMENT PERSPECTIVES

The Comprehension Boost in Early Word Learning: Older Infants Are Better Learners

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ABSTRACT—***Recent research has revealed that infants begin understanding words at around 6 months. After that, infants' comprehension vocabulary increases gradually in a linear way over 8–18 months, according to data from parental checklists. In contrast, infants' word comprehension improves robustly, qualitatively, and in a nonlinear way just after their first birthday, according to data from studies on spoken word comprehension. In this review, I integrate observational and experimental data to explain these divergent results. I argue that infants'*** **comprehension boost** ***is not well-explained by changes in their language input for common words, but rather by proposing that they learn to take better advantage of relatively stable input data. Next, I propose potentially complementary theoretical accounts of what makes older infants better learners. Finally, I suggest how the research community can expand our empirical base in this understudied area, and why doing so will inform our knowledge about child development.***

KEYWORDS—*word learning; language development; language input; infancy*

As parents, pediatricians, clinicians, and developmental researchers know, early language development is remarkable in speed, breadth, and robustness. Incontrovertibly, nature *and* nurture play a role, with environment, biology, and cognitive capacities influencing how we acquire language (Werker & Hensch, 2015). Yet despite more than a century of work documenting infants' language experiences (Darwin, 1877) and decades of research on early language development (e.g., Wanner & Gleitman, 1986), we lack a comprehensive explanation for how children's language input and development give rise to their knowledge. In this article, I argue that such an explanation requires (a) forging stronger links between controlled experiments in the laboratory and children's day-to-day experiences, and (b) understanding early word learning and its links to other linguistic, cognitive, and social skills. I focus on recent work showing that just after age 1, infants' real-time word comprehension improves substantially and why this may be.

It is only in early childhood that we see a big delay between when word comprehension and production emerge. In contrast, kindergarteners shown a new species (e.g., *blickets*) can readily reply, "I like blickets!" Infants have tacit knowledge about words for months before they begin even an approximate production of those words. Recent research has revealed that infants begin understanding words around 6–9 months (Bergelson & Swingley, 2012, 2015; Parise & Csibra, 2012; Tincoff & Jusczyk, 1999, 2012). That is before they have started walking, pointing, or experiencing much agency. But it is not before they have begun leading rich internal mental lives, with expectations about objects, people, and quantities (e.g., Spelke & Kinzler, 2007; Xu & Kushnir, 2013). Although what young infants know outstrips what they readily tell or show us, fine-grained lab measures can capture their knowledge.

In this article, I limit the scope to common, concrete, open-class words learned in infancy, and operationalize understanding a word as thinking of its referent (i.e., meaning) upon hearing it said. Thinking is hard to measure, leading to a reliance on infants' subtle behaviors (e.g., eye movements).

MEASURING SPOKEN WORD COMPREHENSION: RECENT IN-LAB RESULTS

The most common task for assessing early word comprehension is *looking while listening* (Fernald, Zangl, Portillo, & Marchman, 2008). In this task, infants see a display with multiple

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components (e.g., eating and drinking or a blueberry and a banana), and hear an utterance (e.g., "Look, she's eating!" or "Where's the banana?"). Infants' gaze to the named referent is then measured over trials and infants. Such eye-tracking studies usually measure comprehension of 2–16 words, with careful counterbalancing to account for inherent preferences. Several design dimensions influence whether infants succeed in this task, including age, language, word frequency, and the relation between depicted entities (Bergelson & Aslin, 2017; Kartushina & Mayor, 2019). Many of these factors also influence adults' spoken word comprehension in the closely related Visual World Paradigm. This suggests continuity in mental representations across the lifespan. Indeed, in children as in adults, spoken word comprehension is incremental and rapid (Bergelson & Swingley, 2013b).

Early Word Knowledge and the Comprehension Boost

Unsurprisingly, the words infants understand in looking-while-listening studies at 6 to 9 months are common across the circumstances in which they were raised and fairly consistent visually (e.g., foods, body parts, caretakers). A few months later, infants begin to understand more complex words like *uh-oh* and *eat*—while these words are also very common, they appear to take longer to learn, likely because their referents are more ephemeral and visually diverse, and because the words are often said without clarity about what they refer to (Bergelson & Swingley, 2013a). However, something remarkable apparently happens just after the first birthday. Infants get *much better* at understanding words in the looking-while-listening task. Indeed, this improvement appears to be nonlinear, and it is robust regardless of whether infants are tested with still images or videos, nouns or varying parts of speech, familiar images or new ones, or cross-sectionally or longitudinally (Bergelson & Swingley, 2012, 2013a, 2015, 2018; Garrison, Baudet, Breitfeld, Aberman, & Bergelson, 2020; see Figure 1, top panel.)

This nonlinear improvement (hereafter referred to as *comprehension boost*) appears specific to the real-time process of spoken word comprehension as measured by in-lab eye tracking. In

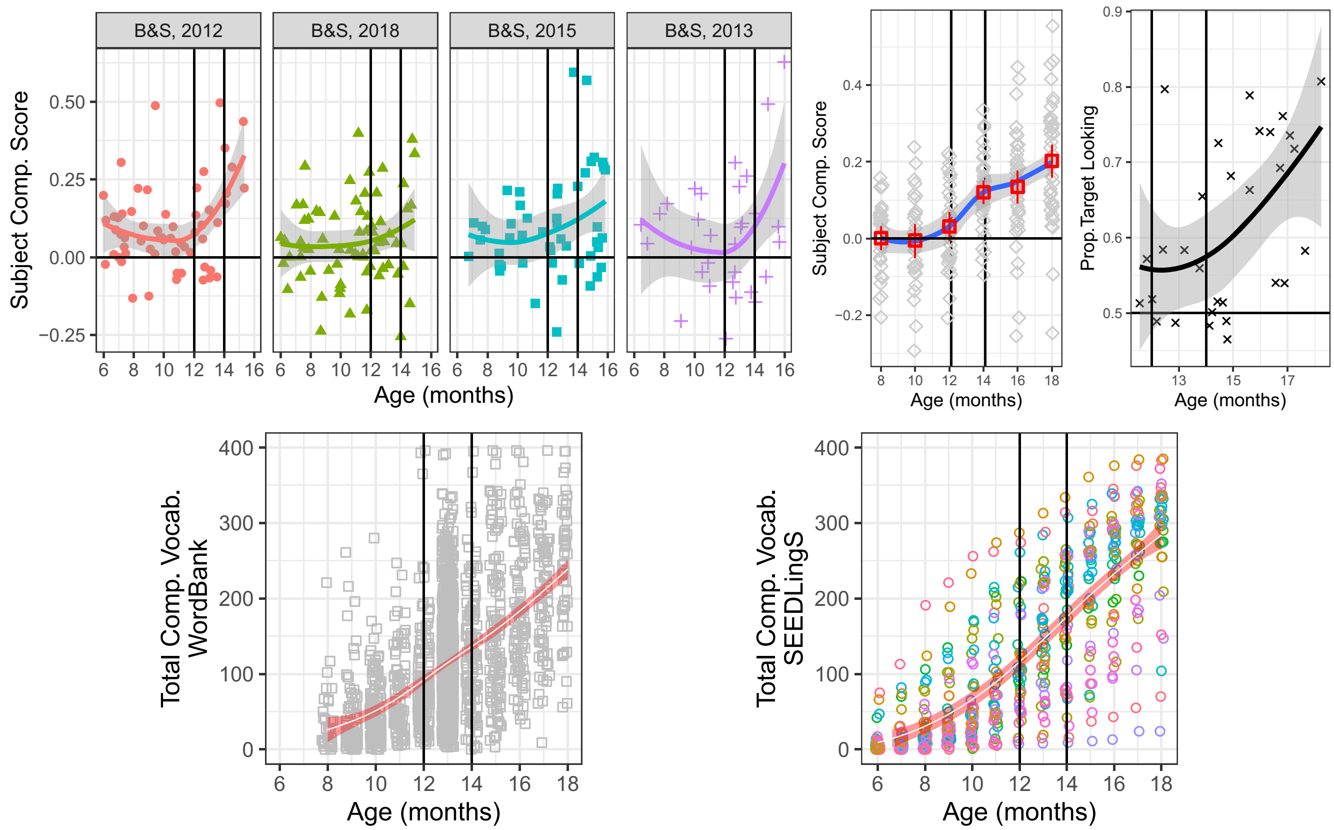

Figure 1. Word comprehension data. Top panel: Six datasets showing nonlinear improvements in online spoken word comprehension (*y*-axis) as a function of age (*x*-axis), as measured in the lab (left to right: Data replotted from four articles by Bergelson and Swingley (B&S + publication year, *n* = 73, 70, 49, 33), Bergelson et al. (2017; *n* = 44 (longitudinal), and Garrison et al., 2020; *n* = 30). 13–38% of infants' mothers have less than a college degree across datasets. Bottom panel: Cross-sectional data (left; from Wordbank, Frank et al., 2020; *n* = 1,804; of the 59% reporting maternal education, 55% have less than a college degree) and longitudinal data (right, from Bergelson, 2016; *n* = 44; 25% of infants' mothers have less than a college degree), showing gradual increase in overall vocabulary with age, in contrast to the top panel's real-time comprehension data. Bottom right panel and fifth-top panel show longitudinal data from the same children, highlighting the nonlinear versus linear shift in in-lab word comprehension versus overall reported comprehension vocabulary. Vertical lines show the onset of the comprehension boost, ~12–14 months. [Color figure can be viewed at wileyonlinelibrary.com]

contrast, when parents are asked to check off words on a list they believe their child understands (e.g., with the MacArthur-Bates Communicative Development Inventory; Fenson et al., 1994; Frank, Braginsky, Yurovsky, & Marchman, 2016), no such boost is evident. That is, infants' comprehension vocabulary based on parental reports shows gradual, linear, improvements over 8–18 months (see Figure 1, bottom panel.)

The linearity in parental reports may be the true developmental pattern, rather than the boost found in lab studies. But this seems unlikely since lab studies provide an objective, direct measure of comprehension that does not rely on parents' (variable) intuitions, theory of the task, or inference, as the parental checklist does (cf. Frank, Braginsky, Marchman, & Yurovsky, 2020; Tomasello & Mervis, 1994, on the challenges of *comprehension* checklists).[1] In other words, given concerns inherent in parental reports for comprehension, the most parsimonious interpretation appears to be that this method obscures the result that more fine-grained in-lab eye-tracking methods reveal: Infants' moment-by-moment spoken word comprehension improves robustly around 12–14 months.

WHAT UNDERLIES INFANTS' ROBUST IMPROVEMENT IN WORD COMPREHENSION IN YEAR 2?

Language Input

One potential explanation for the comprehension boost observed in the lab is that language *input* to children changes with age, and that this drives a boost in comprehension. That is, if parents' production of common nouns increases greatly over the first year, this may spur the comprehension boost: Hearing words more often would provide more opportunities to infer, learn, and retain their meanings.

However, in a longitudinal study consisting of monthly daylong audio recordings and hour-long video recordings of naturalistic interactions in infants' homes from 6 to 17 months (Bergelson, 2016), this does not appear to be the case. Across several metrics linked to language development (Bergelson & Aslin, 2017; Rowe, 2008), infants' noun input was highly *variable* across children, but was also very *stable* within children (and the group) from month to month.[2] Specifically, month-by-month measures showed strong consistency over this age range in the quantity of words, talkers, types of utterance, and referential context that infants experienced when hearing common nouns (see Figure 2). Nevertheless, their comprehension improved palpably around age 1.

Thus, it appears that the comprehension boost comes from *within the learners* themselves: Children take greater advantage of language input, which remains quite steady over infancy, across several relevant language properties. That is, changes in language input does not seem to explain the comprehension boost.[3] Next, I turn to two theoretical accounts of what change within the learner might entail: the accumulator model and the better learner model.

Accumulator Models

In the broader literature, accumulator models accrue information from sampling (e.g., Gallistel & Gelman, 1992); such models have been applied to language learning (Hidaka, 2013; Mollica & Piantadosi, 2017). In the case of online word comprehension, accumulator models would involve some sort of threshold, so that after experiencing X "good" learning instances, infants link words to meanings more robustly, leading to the observed nonlinear improvement after 12 months. That is, the *rate* of information (e.g., number of noun tokens per month) is less relevant than its *accumulation*, with consistent accumulation across children at around age 1 leading to the comprehension boost.

Such data-driven models have been proposed to explain the growth trajectories of children's overall comprehension and production vocabularies (Mollica & Piantadosi, 2017). Specifically, "...words require on the order of ~10 learning instances, which occur on average once every two months ... maturational factors play little role in learning as measured by comprehension" (Mollica & Piantadosi, 2017, p. 67). While elegantly modeled, this account does not define good or effective learning instances, making it difficult to falsify.

Indeed, evaluating an accumulator model seriously requires further modeling, as well as experimental and observational research. For instance, if maturational factors truly play little role, then exposure to more instances of a word should lead to better knowledge of *that* word, independent of age (i.e., maturational state). While this is trivially false for newborns (who will not demonstrate knowledge of the word *ball* no matter how many exposures they receive), one could still evaluate this with 10- to 18-month-olds by systematically exposing them to new words and establishing (a) whether there is indeed an exposure threshold leading to robust learning (which just happens to occur around 12–14 months for common words) and (b) whether learning is predicted by exposure alone (rather than age also accounting for significant variance, in contrast with a simple accumulator model).

A second way to evaluate an accumulator model is to propose the learning contexts that provide "effective" learning instances and test them parametrically. Research on language development has many suggestions about what makes learning instances

[1]That said, there may be nonlinguistic, task-relevant skills that independently improve around 12–14 months and support the comprehension boost; this possibility is addressed in the section on social and cognitive development.

[2]Four out of the six datasets in the top of Figure 1 show noun comprehension, also the focus of the home recordings.

[3]Both the comprehension boost and cross-age input stability reported here largely reflect mid- to high-socioeconomic-status (SES) U.S. families (see figure captions). How this generalizes across SES is an important question, particularly given results showing that SES influences both real-time word comprehension and language input in toddlers in the United States (Fernald, Marchman, & Weisleder, 2013; Weisleder & Fernald, 2013).

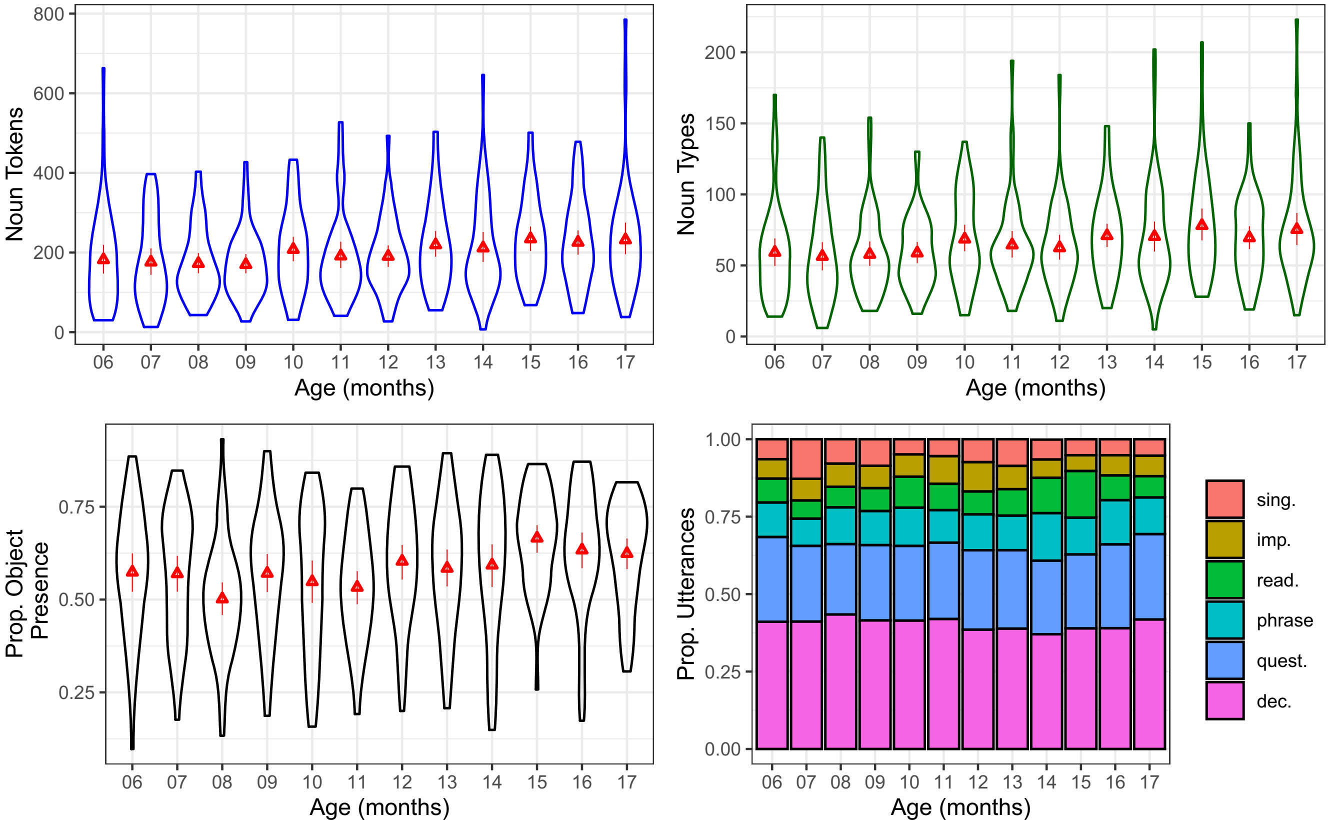

Figure 2. **Input descriptives. Forty-four infants' noun input in monthly hour-long home video recordings across four key language metrics (*x*-axis: age; *y*-axis: metric) [corpus: Bergelson, 2016; cf. Bergelson et al., 2018; 25% of infants' mothers have less than a college degree]; critically, nouns in infants' language environment are highly stable month-to-month across the depicted age-range. Metrics, clockwise, are: number of total words (tokens; blue violin plots), number of unique words (types; green violin plots), referential transparency (i.e. object presence; black violin plots), and utterance type (colored bars indicated the proportion of nouns heard in singing, imperative, reading, short phrase, question, and declarative utterances). In the first three panels, the red triangle and error bar indicate *M* + 95% bootstrapped CI; violin width represents amount of data in that portion of the distribution, that is, the variability across infants. [Color figure can be viewed at wileyonlinelibrary.com]**

effective, including referential transparency, spaced exposure, and child-contingent engagement (Baldwin, 1993; Bergelson & Aslin, 2017; Childers & Tomasello, 2002). To test such properties' efficacy within an accumulator framework, researchers could model word learning while holding age constant and manipulate the number of putatively effective learning instances children receive. Uncovering how to promote effective word learning may prove independently useful for educational applications.

Notably, previous research suggests that at least some properties that promote effective word learning are likely to vary as a function of age (Carpenter, Nagell, & Tomasello, 1998). While a shifting notion for what is effective is largely antithetical to an accumulator account, it squares nicely with a better learner account, which I address next.

Better Learner Models

In contrast to the simpler accumulator model, the better learner account proposes that the comprehension boost is undergirded by infants' growing social, cognitive, or linguistic skills.

Social and Cognitive Development

One possibility is that an improved ability to share attention leads to the comprehension boost. Indeed, researchers suggested this possibility decades ago as the reason word learning does not begin until age 1 (e.g., Tomasello, 2001). Given data from the intervening years cited earlier, this suggestion may be reasonably amended to say growing social skills may be why word learning *takes off* around 12 months, rather than beginning then.

Further potential evidence for social skills supporting word learning comes from a recent study that used electroencephalography to look at word comprehension in the context of social interaction (Forgács et al., 2019). Fourteen-month-olds tracked who knows what during an object-labeling scene, which in turn predicted their electrophysiological brain responses to word-object mismatches (Forgács et al., 2019). This kind of social awareness may facilitate word comprehension.

Basic cognitive abilities have also been tied to early language (Rose, Feldman, & Jankowski, 2009). In one study, memory and representation tasks (e.g., delayed recall and object permanence) correlated with comprehension vocabulary scores at 12 and 26 months, though not all cognitive tasks showed this effect (e.g., attention tasks were unrelated to vocabulary), suggesting differentiable relations between cognitive and linguistic abilities (Rose et al., 2009). Given that some elements of memory and object knowledge seem to improve around 12 months (e.g., infants cease making the a-not-b error), these cognitive skills may help undergird the comprehension boost.

Finally, *both* cognitive and social growth may convergently support word comprehension. For instance, pointing is argued to drive attention, enhance social interaction and intention sharing, and function symbolically. It may be no accident that pointing begins just a few months before the comprehension boost occurs (Colonnesi, Stams, Koster, & Noom, 2010; Moore, Dailey, Garrison, Amatuni, & Bergelson, 2019).

One approach to testing the potentially relevant skills I have mentioned is conducting multiple tasks spanning the comprehension boost. For instance, combining an attention-sharing task, an object-permanence task, and a word-comprehension task longitudinally at 11, 14, and 17 months may clarify whether improvements in cognitive and social tasks map onto the word-comprehension boost in an explanatory way.

Linguistic Development

Another version of the better learner account concerns linguistic development. Just as in the cognitive and social realm, infants acquire several skills over the first year of life that might serve as potential prerequisites for the comprehension boost. For instance, speech segmentation (i.e., figuring out where words begin and end) is a critical component for parsing the speech stream, which in turn helps infants connect words with meaning. Researchers have linked speech segmentation and word knowledge both concurrently and longitudinally (Lany, Shoaib, Thompson, & Estes, 2018; Singh, Steven Reznick, & Xuehua, 2012). In one study, 15-month-olds' syllable-based sequential pattern learning predicted variance in language-processing efficiency during spoken word comprehension (Lany et al., 2018). In another study, this one longitudinal, 7½-month-olds' segmentation abilities were associated with productive vocabulary at 24 months (Singh et al., 2012). Taken together, these studies point to speech segmentation as a potential prerequisite for the comprehension boost.

Before their first birthday, infants can also use phrasal prosody (i.e., rhythmic and intonational markers that separate phrases) to identify and learn new words (e.g., Shukla, White, & Aslin, 2011). Related recent work suggests that 1½- to 2-year-olds use function words and prosody to help them learn new words (de Carvalho, He, Lidz, & Christophe, 2019). Thus, another potential prerequisite for the comprehension boost is the ability to use phrasal prosody and function word cues effectively.

However, other than one study (Lany et al., 2018), research has not directly linked infants' comprehension of common words from everyday life (i.e., the words for which we see the boost) with speech segmentation, phrasal prosody, or syntactic cues. One way to test links between these skills is the multiple-task approach, as outlined earlier for social and cognitive skills.

Another way to test how linguistic skills build on each other is to investigate whether infants' growing language abilities allow them to listen more predictively. That is, prompted by "Where's the banana?" younger infants may hear "bla bla banana?" In contrast, before even hearing *banana*, older infants anticipate a noun and more generally expect grammatical utterances (Booth & Waxman, 2008; Kedar, Casasola, Lust, & Parmet, 2017). By disrupting the predictability of the sentence (e.g., scrambling its words or prosody), researchers could determine whether predictive listening forms a potential prerequisite underlying the comprehension boost.

Yet another possibility is that the onset of word production supports the comprehension boost. First words generally emerge just before infants' first birthday, in both parent report and naturalistic samples (Fenson et al., 1994; Frank et al., 2016; Moore et al., 2019). The onset of word production may spur increased metalinguistic awareness (e.g., "Aha, we humans use words to refer to the world!"), which in turn boosts comprehension. Researchers could test this idea through nonlinear modeling (e.g., change-point analyses), probing whether production onset spans the comprehension boost, though first words are notoriously difficult to determine (Moore et al., 2019; Vihman & McCune, 1994). Another tack would be to establish whether and when late talkers show a comprehension boost, though disentangling late-but-normative from late-and-atypical talkers complicates this approach (Prelock & Hutchins, 2018).

Contingent Acquisition

A further consideration for the better learner account concerns a distinction between developmental factors (i.e., maturation/cognitive development) and an intrinsic order of operations regarding learning. In research on the interface between early grammar and the lexicon, this distinction, dubbed *contingent acquisition*, refers to the idea that children need to know some aspects of language before they can learn other aspects well (or better or more efficiently; Snedeker, Geren, & Shafto, 2007). To test this idea, researchers compared English-learning toddlers who were international adoptees with English-learning infants who were not: Both groups had been learning English for the same amount of time, but varied in age (and thus maturation and cognitive development; Snedeker et al., 2007). Despite their 2-year age gap, both groups used short sentences, often omitted grammatical markers, and had an early productive vocabulary dominated by nouns. This led the authors to conclude that for those aspects of language, early language representations facilitated later ones, rather than maturation or cognitive development acting as a gatekeeper. This may also be the case for the comprehension boost; this is ultimately an empirical question. While developmental and contingent factors are typically confounded (as noted by Snedeker et al., 2007), both are compatible with a better learner account.[4]

SUMMARY

The research I have reviewed in this article suggests a nonlinear, arguably *qualitative* shift in infants' real-time word comprehension just after the first birthday. I have explored different accounts to explain what may underlie this comprehension boost. First, relying on naturalistic observational data, I provided evidence that infants' language input for common nouns (which make up most of the early vocabulary; Frank et al., 2016) is quite stable across 6 to 17 months, at least in the sample studied. Then, I discussed two possible accounts for the comprehension boost: an accumulator account and a better learner account (and its cognitive, social, and linguistic versions). While these two accounts are not directly compatible, the different versions of the better learner account are. That is, both nonlinguistic and linguistic improvements in year 1 may undergird the comprehension boost; this, too, is an empirical question.

Throughout the article, I have included suggestions for testing each potential support or predictor of the comprehension boost. This is worth doing for two reasons: First, doing so may bolster the basic science underlying an early critical step of perhaps our most unique human skill: language. Second, early language development is critical for many subsequent developmental cascades, within and outside the language domain (Bornstein, Hahn, Putnick, & Pearson, 2018). Early language concerns are generally addressed when infants are late to start talking, which is months to years after they have begun understanding words. Moreover, disparate language diagnoses are often lumped together and treated similarly, despite divergent underlying causes. A clearer understanding of how word learning gets off the ground will permit a stronger evidence base for more effective, earlier diagnosis and intervention in cases of atypical language development and provide deeper insight into the human mind.

I close with three central suggestions for child development researchers. First, it is fruitful and important to conduct complementary, iterative research across lab and home settings (ideally with the same children). Second, to uncover changes and links across developing skills, longitudinal designs with multiple tasks are a strong way forward. And third, as a field, we must move beyond the nonrepresentative populations we tend to study because of limits to the generalizability of such samples across many domains (e.g., Karasik, Adolph, Tamis-LeMonda, & Bornstein, 2010). In this article, I have focused on typically developing English-learning U.S. infants from mid- to high-SES backgrounds (i.e., the most common population sampled in research on language development). We should all move beyond such samples to not only invest more time and effort in understanding atypical development, but also to explore child development across a broader range of languages, cultures, and upbringings. Taken together, these suggestions will lead to a richer and more encompassing understanding of how infants learn and grow.

[4]As noted in footnote 3, SES influences both language input and comprehension in U.S. toddlers; as such, studying infants of varying SES may provide leverage in determining the relative roles of earlier language representations versus developmental factors in driving better learning.

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