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Authors
Bergelson, Elika
Swingley, Daniel

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Social and Environmental Contributors to Infant Word Learning

Elika Bergelson (elikab@psych.upenn.edu)
Department of Psychology, 3401 Walnut St, 400a
Philadelphia, PA 19104 USA

Daniel Swingley (swingley@psych.upenn.edu)
Department of Psychology, 3401 Walnut St, 400a
Philadelphia, PA 19104 USA

Abstract

Infants demonstrate comprehension of early nouns (e.g. "hand") around six months, and comprehension of early non-nouns (e.g. "eat") around 10 months. In two experiments, we explore the reasons for this lag. Expt. 1 is a gaze-following study, the results of which suggest an improvement in point-following around ten months, and reveal correlations between pointing and both overall and non-noun vocabulary. Expt. 2 is a set of corpus analyses, the results of which suggest that word frequency does not explain the difference between noun and non-noun age of acquisition, while suggesting that the co-presence of words and their referents may play an important role. The results of these experiments contribute to our understanding of word-learning across word classes, and lend support to environmental and social factors as having an impact on the trajectory of word learning in the first year of life.

Keywords: language acquisition; word learning; cognitive development; infancy; psycholinguistics; corpus analysis

Introduction

Infants learn words by taking in the environment around them and, over time, creating links between bits of language and bits of the world, with abstraction at both ends. Not all words are learned with equal ease, a phenomenon having the potential to help explain how word learning works. Diary studies and databases of parental checklists show that infants' early comprehension and production vocabularies, while quite broad, numerically favor nominals over action words, modifiers, and social expressions (Benedict, 1979; Dale & Fenson, 1996).

These findings agree with comprehension studies in which infants who were asked to look at referents of nouns like "apple" and "hand" succeeded by 6 months of age (Bergelson & Swingley, 2012a; Tincoff & Jusczyk, 1999, 2012), but did not reliably show understanding of non-nouns like 'uh-oh' and 'eat' until around 10 months of age (Bergelson & Swingley, 2013; See table 1).

The reasons for this developmental lag could rest within the child, within the nature of the linguistic elements, or within the environment. Here, we examine several broad hypotheses about the source of this lag, which we consider in light of new behavioral research (Expt.1) and corpus analyses (Expt. 2). These hypotheses are not new, and have been the focus of a great deal of research, primarily among children older than the infants we consider here. Studies show that each of the factors we examine is very likely to be important at some point in development. What we begin to address here is the extent to which they might explain the developmental course we have found in infants' word understanding.

Frequency

The Frequency hypothesis maintains that nouns are more frequent than non-nouns in infants' early experience, and that this leads to their being learned earlier, once a sufficient mass of exposure has occurred. Frequency may aid learning because learning is incremental over exposures, or because with more tokens the likelihood of a very useful exposure instance increases (Medina, Snedeker, Trueswell, & Gleitman, 2011).

This hypothesis has several forms. The simplest is that infants just hear the non-nouns less often than the nouns. A more specific hypothesis is that infants hear nouns in *isolation* (in one-word utterances) more often than non-nouns, which might lead to earlier learning of nouns (Brent & Siskind, 2001). We can evaluate whether frequency differences might explain infants' relatively late learning of non-nouns by measuring whether there are corpus frequency differences between the tested nouns and non-nouns.

Environment

The Environment hypothesis we consider here maintains that nouns and non-nouns differ in the degree to which the contexts of their typical use support learning, where "support" refers to environmental conditions that prior research suggests are relevant to word learning. For example, non-nouns may appear in a broader number of situation-settings (e.g. playing, eating) than nouns, or may involve different amounts of attention-getting movement. Parents' use of nouns may go along with tactile support or clear signs of visual attention. Nouns may be used more often while the referent is present than is the case for non-nouns. All of these features are reasonable candidates as factors that support word learning (e.g., Kersten & Smith, 2003; Meyer, Hard, Brand, McGarvey, & Baldwin, 2011; Tomasello & Kruger, 1992).

Social Skill

The Social Skill hypothesis maintains that between six and ten months infants gain skills of social cognition that underlie the capacity for learning more abstract words—skills that might not be criterial for learning nouns but which, by hypothesis, may be imperative for learning non-nouns. Existing research points to important changes in social-cognitive skills in the second half of the first year. For example, gaze-following improves substantially over this period, and may facilitate word learning (Morales, Mundy, & Rojas, 1998). Evidence of increasing social skills around 9-10 months indirectly supports the possibility that a social skill that was not necessary for learning nouns may be necessary for learning non-nouns. Prior experiments testing gaze-following showed that 10– and 11-month-olds but not 9-month-olds were more likely to follow the gazer's regard when his eyes were open than when they were closed, and that this skill correlated with language scores at 18 months (Brooks & Meltzoff, 2005; Brooks & Meltzoff, 2008).

Conceptual Difficulty

The Conceptual hypothesis proposes that non-nouns are harder to learn because of the nature of the concepts and categories involved. Instances of a word like 'uh-oh' vary more and thus may be harder to recognize as having a common semantic core than instances of 'hand'. This hypothesis can be expressed as stemming from higher-level differences in the kinds of linguistic roles played by nouns in contrast with adjectives, exclamations, verbs, and social greetings. It can also be thought of as a low-level difference in what 'features' must be summed over: in the noun case, visual features such as shape, size, and color, in the case of e.g., banana, which may be easily graspable from the environment, while non-nouns require more abstract (perhaps second-order) features that are harder to posit or grasp. A related hypothesis concerns biases in word-learning; it could be the case that in the absence of further evidence, infants choose to posit that a new content word they have isolated from the speech stream refers to a noun before they consider that it may refer to another part of speech.

Overview of the Present Research

The hypotheses laid out above overlap; for example, conceptual difficulty might cause a need for social skills in learning non-nouns. Still, evidence can be brought to bear that favors or disfavors these hypotheses. Our two concrete research questions are:

1) Do we find evidence that gaze- and/or point-following correlate with early word comprehension in laboratory tasks and/or vocabulary checklists?

2) Are there frequency-based or environmental differences between nouns and non-nouns when examining naturalistic interactions between infants and their caregivers?

In Expt. 1 we tested 6-14 month olds (n=37) in a gaze-following task. Parents also completed vocabulary checklists (MCDI, Dale & Fenson, 1996). Most of these subjects (n=25) also participated in a noun comprehension eyetracking study on the same day. The goal of this experiment was to look for specific mappings between social behaviors and word understanding. To date we have tested individual infants on nouns and on gaze following, with the intent to examine non-nouns and gaze following as well; this study speaks to the Social Skill Hypothesis.

In Expt. 2 we investigated how nouns and non-nouns appear in infants' environment, through analyses of audio and video corpora of infants interacting with their caregivers, with the goal of gaining a better understanding of whether the environment of these two types of words differs in relevant ways. If frequency and environmental factors affect noun and non-noun learning differentially, we expect to find differences in these measures across the word types in the corpus. This study speaks to the Frequency and Environment hypotheses.

In both studies we used a set of nouns and non-nouns tested in previous eyetracking studies (Bergelson & Swingley, 2012a, 2013). See Table 1.

For both sets of items a corpus of 16 mothers speaking to their infants (Brent & Siskind, 2001), and a database of vocabulary checklists (MCDI, Fenson et al., 1994) were used to select a pool of items that were used often by most mothers and reportedly understood by a large percentage of 12-18 m.o. infants. Items were then selected among candidates based on imageability, and phonological properties.

The nouns are all foods and body parts, as the authors had a secondary interest in these abstract categories as such. , Given that infants early vocabularies are indeed a smorgasbord of different parts of speech (Benedict, 1979), and that is it not always easy to determine that the word class an item belongs to for a young infant corresponds to its word class in adults' vocabulary, the non-nouns were simply the most common imageable words heard by infants that were not concrete objects

Non-Nouns	all gone, bye, dance, drink, eat, hi, hug, kiss, more, sleeping, smile, splash, uh-oh, wet,
Nouns	apple, banana, bottle, cookie, ear, eye/s, face, foot/feet, hair, hand/hands, leg/s, milk, mouth, nose, spoon, yogurt

Table 1: Previously Tested Nouns and Non-Nouns

Experiment 1

Methods

Participants

The gaze-following study tested 37 infants (R= 6.0-14.9mo., M=9.8mo.), of which 25 infants also participated in a word-comprehension study just prior to the gaze-following study (R=6.6-12.8 mo., M=9.2mo.).

All participants were healthy, typically-developing monolingual English-exposed full-term infants with normal hearing and vision, recruited in the Philadelphia area. 8 additional infants were excluded from the gaze-following study (technical error, n=5; fussiness, n=1; parental interference n=1, premature birth status n=1); 10 additional infants were excluded from the word-comprehension study (technical error, n=6; fussiness, n=2; parental interference n=1, premature birth status n=1).

Design

All parents first completed consent, background, and vocabulary checklist forms. Infants sat on their parent's lap and watched short video clips on a computer outfitted with a remote eyetracker (Eyelink, SR Research). Parents wore a visor to block their view of the screen, but not of their child. Infants wore a small sticker on their forehead to facilitate tracking. After calibration, infants saw a series of 16 test trials. In each test video, infants saw an actress with two toys, one on either side of her. At the beginning of each clip, the actress looked down at the table (2s), looked up at the camera and smiled (3s), and then turned her head to the left or right and *gazed* (*gaze* trials, n=8) or g*azed* and *pointed* (*point* trials, n=8) to one of two toys[1]. She kept her gaze there until the trial ended (5s; this was the time window of interest, hereafter "post-turn window"). Each video was 10s long, and side of look, point, and toy were counterbalanced within and across subjects.

For the infants in the word comprehension study, the design was identical to that in Bergelson & Swingley, (2012a), except that the experimenter spoke the words in lieu of the parent (as in Bergelson & Swingley, 2012b). Briefly, infants were presented with images of foods and body-parts, one of which was named by the experimenter, while their eyegaze was monitored.

Data Analysis

We quantified infants' performance in the gaze-study as *proportion target looking*. For each subject, we computed a difference score consisting of the proportion of infant gaze to the target, minus the proportion to the distracter, averaged over trials. This measure ignores gaze at the actor's face or hand and compares correct and incorrect looks. Indiscriminate looking at target and distracter would yield, on average, a score of zero.

Given our interest in infants' increased comprehension of non-nouns at ten months, we split subjects into two groups around this age.

We also correlated infants' performance in the gaze-following study with two different vocabulary measures: MacArthur CDI scores and noun-comprehension subject

means. MCDI scores were calculated based on the number of words parents said their child understood or said on the MCDI; we looked at MCDI scores overall, and at the specific sets of nouns and non-nouns for which we found a developmental lag (Bergelson & Swingley, 2012a; 2013, see Table 1). Noun-comprehension subject means were calculated from infants' performance in the noun-comprehension experiment that preceded the gaze-following study.[2]
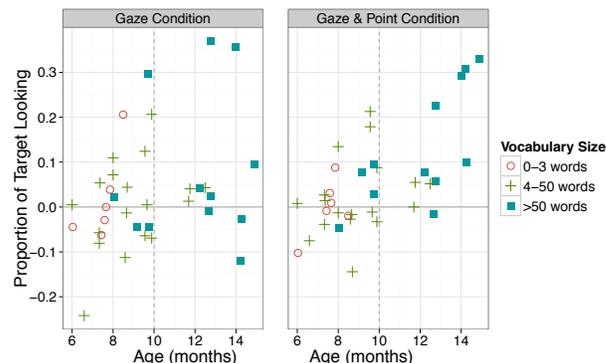

Figure 1: Expt. 1 Subject Means by Age in the Gaze- and Point-Following Task. Each dot represents each subject's proportion of target looking averaged over trials, for each condition. The symbol used for the dot represents infants' vocabulary size, binned into three groups (see legend). Infants performed above chance in the Gaze & Point condition in the over-10 month age group (the right side of the right graph).

Results

Across both age groups, infants failed to look more to the side the actress looked at on *gaze* trials (<10 mo.: 12/26 infants with positive performance, M=.012, Mdn=-.00019, p=1; >10 mo.: 8/11 infants, M=.031, Mdn=.041 p=.10).[3] For *point* trials, infants under 10 months performed at chance (14/26 infants, M=.023, Mdn=.018, p=.35), while infants over 10 months succeeded (9/11 infants, M=.13, Mdn=.15 p=.008).

We next examined the correlations between infants' vocabulary size, as reported by their parents, and their gaze-following behavior. Infants' MCDI scores correlated with proportion target looking on point trials, but not on gaze trials (point trials: (Kendall's) τ=.26, p=.024; gaze trials: τ=.09, p=.43). Looking at the MCDI subset containing nouns and non-nouns that were tested in previous eyetracking studies (Bergelson & Swingley, 2012a, 2013), we found correlations between point trials and non-noun vocabulary (τ=.28, p=.019) and a marginal

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[1] Point-only trials were not included given that such trials would pit gaze and point against each other; moreover, pointing one place and looking another is rarer in day-to-do life.

[2] For details on how subject means were computed, please see Bergelson & Swingley, 2012.

[3] All subsequent tests are two-talked Wilcoxon tests unless noted otherwise; all "X/X infants" results indicate the number of infants with positive performance. M is mean; Mdn is the pseudo-median estimate of the Wilcoxon test.

correlation between point trials and noun vocabulary (τ=.21, p=.080). Noun and non-noun correlations with gaze trials were not significant (non-nouns: τ=.022, p=.89, nouns: τ= .11; p=.37). For the subset of subjects in the noun-comprehension study (n=25), performance in the gaze-following study and noun-comprehension study were not significantly correlated (gaze trials: τ=.11, p=.44, point trials: τ=-.05, p=.73). See figure 1.

Discussion

These results suggest that around ten months, when infants begin to show comprehension of non-nouns, they show an increase in their ability to follow pointing and gaze, but not gaze alone. This ability is correlated with non-noun and overall vocabulary, assessed by parental checklist.

While previous work has found links between infants' gaze-following and vocabulary size at 18 months (Brooks & Meltzoff, 2005), here we find a correlation between point-following and current vocabulary size, and in particular, with knowledge of non-nouns tested in previous work.

The finding that infants' noun comprehension task behavior did not correlate with point-following is in keeping with the marginal correlation we found on the MCDI noun subset. The possibility remains that although noun comprehension is evidently not strongly correlated with point-following ability, non-noun comprehension may be, a hypothesis we cannot address directly yet.

Vocabulary size and age are correlated (τ=.46, p<.0001). This makes it difficult to untangle their relationship to point-following[4]. However, the results suggest that point-following seems to be a categorical ability attained around ten months (See figure 1). Before ten months, performance is variable and centered around zero; after ten months virtually all children are above zero. This, coupled with the result that age and residualized vocabulary both predict pointing suggests that age and vocabulary are not redundant predictors.

Thus, in answer to our first question, the timing of point-following success and correlations between MCDI and point-following data provide indirect evidence for the Social Skills Hypothesis. Thus, point-following is a strong candidate social skill that might be useful in non-noun learning but which is apparently not necessary for noun learning, inasmuch as our somewhat exaggerated pointing materials test point-following in natural contexts. An alternate possibility is that a third skill emerges around ten months, and that this skill mediates both point-following and non-noun learning.

Thus, with evidence for the social hypothesis garnered in Expt. 1, we turn to a set of corpus analyses that will allow us to assess the roles of frequency and environmental factors in the lag between noun and non-noun learning.

Experiment 2

Methods

We examined mothers' use of the set of nouns and non-nouns that we have tested in eyetracking experiments in both the Brent Corpus (an audio corpus of 16 mothers interacting with their 9-15 m.o. infants; Brent & Siskind, 2001), and in 20 videos of the Providence Video Corpus (5 mothers interacting with their young children; we selected a subset in which children ranged from 11 to 18 mo; Demuth, Culbertson, & Alter, 2006). In the Brent Corpus we compared frequency counts in isolation (i.e., in one-word utterances) and overall. In the Providence corpus we extracted 919 utterances in which both the caregiver and child were clearly visible, and in which one of our words of interest was said.

These utterances were coded for a number of features, including whether the referent of the word was present (e.g. is there an apple when 'apple' is said, is someone eating when 'eat' is said, did something fall accidentally when 'uhoh' was said, etc.), what the parent was looking at/touching, what the child was looking at/touching, the situation the word was used in, what (if anything) was moving, whether the word was said before, during, or after attention to the relevant referent transpired, and what was present in the room. In the case of body-parts, coders noted 'presence' only when the relevant part was involved in the interaction in any important sense: e.g., if the mother was looking at a child who had yogurt all over her mouth and said "look at your messy face!" this counted as 'presence' of the word 'face'; in contrast, if the mother was holding her crying child while singing "if you're happy and you know it clap your hands", this did not count as an instance in which 'hands' were considered 'present'.

Results

A series of analyses was conducted to test whether the difference in eyetracking-task performance between non-nouns and nouns might be due to higher frequency of the nouns rather than something more fundamental about the words' meanings. Frequency was estimated using the Brent corpus. There was not a significant difference in the frequency of the nouns and non-nouns[5]. Descriptively, each noun occurred 45-562 (M=262, Mdn= 244) times within the corpus while each non-noun occurred 33-1292 (M=453, Mdn= 219) times. Across each set of words, the total number of usages did not vary significantly (244 vs. 219, p=.98 by Wilcoxon test). Given that previous research supports a link between word learning and

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[4] In a linear model pointing behavior is significantly predicted by both age, and by vocabulary residualized by age, suggesting that vocabulary predicts behavior above and beyond age alone.

[5] Within each corpus's frequency counts, we did not constrain word class; 'kiss' occurring as a noun or verb was counted for 'kiss', just as 'apple blueberry sauce' was counted for 'apple'.

frequency of isolated word tokens (Brent & Siskind, 2001), we also examined this variable here. The sets of words were not differentially likely to occur in isolation either: nouns occurred 2-92 (M=26) times and non-nouns occurred 0-1091 times (M=152); this difference was not significant (noun Mdn=19, non-noun Mdn=11; p=.95 by Wilcoxon test.).

Analyses of the Providence Corpus subset revealed that there too, our nouns and non-nouns occurred with similar frequency: each non-noun occurred 1-94 times (M=37, Mdn=23), there were 523 non-nouns total. Nouns occurred 5-46 times (M=21, Mdn=19), with 396 nouns tokens total (estimated difference per word type: 7 words; p=.29 by Wilcoxon test over words). Similarly, nouns and non-nouns as a group did not differ in number of isolated occurrences (72 isolated non-noun tokens total, R=1-7 over words; 35 isolated noun tokens total, R=1-3 over words; estimated difference 1.8 words; p=.13 by Wilcoxon test over words).

Hand-coding of interactional features during parental use of the tested words revealed a large word-type (noun versus non-noun) difference in whether the referent of the word was present as part of the interaction. Non-nouns were said much more often than nouns when their referent was not present—e.g., saying "hi!" when no-one was newly on the scene, or "kiss" when there were no evident attempts at kissing. By contrast, nouns ("a banana!") were more often spoken in the presence of the referent (an actual banana, or a picture of one). For non-nouns the referent was not present 39% of the time; for nouns, 15**%**. This pattern held for 5/5 children in the corpus, and was significant over words (estimated difference =.24, p<.012 by Wilcoxon test over words). See figure 2.

No significant difference between word-types was found in what mothers or children were touching or looking at, the number of situation-types that the word occurred in (e.g. playing, eating, interacting, book-reading), what in the scene was moving (e.g. child or mom, their hands, other objects, etc), whether the word was said before, during, or after attention to the relevant referent transpired, nor what was present in the room (all ps>.05 by Wilcoxon tests, and not significant predictors in logistic regressions of word-type). In short, on most coded variables, nouns and non-nouns did not differ in various features of the learning environment–except whether the referent was present or not.[6]

Discussion

Expt. 2 showed that nouns are used in speech to infants when their referents are present; non-nouns are used when their intended referents are present about 60% of the time. However, nouns and non-nouns appear to be said at equivalent rates both in sentence context and as one-word utterances.

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[6] Separate analysis of non-nouns as verbs and performatives showed the same overall pattern as non-nouns combined.

These findings fail to support the Frequency Hypothesis, and lend support to the Environmental Hypothesis, insofar as we found non-nouns were said more often in less ideal learning environments (i.e. when the referent was not present). While it remains possible that other environmental factors varied across the words as well, of those we coded this was the only one that differed significantly across word groups.

One limitation of this study is that the videos were of infants older than ten months, leaving open the possibility that at younger ages there are other word-type differences. Such an account would stipulate that parents interact differently with children once children know some non-nouns.

Thus, in response to our second question, when examining naturalistic interactions between infants and their caregivers, we did not find support for frequency-based differences between nouns and non-nouns, but did find support for environmental differences.
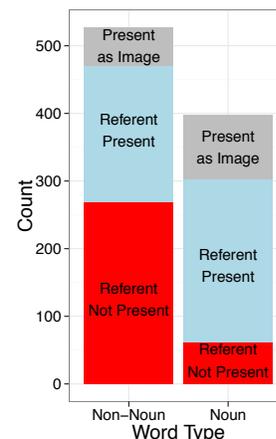

Figure 2: Referent Presence as a function of Word-type in the Providence Corpus Subset. This figure depicts the counts of instances of nouns and non-nouns of interest (see table 1). Color distinguishes whether the referent was present as an image (top), present (middle) or not present

General Discussion

In two studies we have explored the underpinnings of early word learning, seeking to explain why infants are able to understand different types of words at different ages. More specifically, through a gaze-following experiment and corpus analyses, we have sought to explain infants' ability to understand nouns around six months and non-nouns around ten months.

We found some support for the Social Hypothesis, in that point-following emerged around ten months and was correlated with overall vocabulary and, more strongly, non-noun vocabulary. We found support for the Environmental Hypothesis in that nouns were used in the presence of their referent with much greater regularity than was the case for non-nouns. We did not find support for the Frequency Hypothesis, or for other versions of the

Environmental hypothesis related to situation, attention, or motion-related factors.

Both of these experiments leave open the Conceptual Hypothesis, whereby non-nouns are learned later because they are more complicated, either due to the inherent linguistic word-class that the words belong to, or due to the nature of the visual features that need to be tracked to learn non-nouns as opposed to nouns. One way to examine this hypothesis is to teach infants novel nouns and non-nouns in very similar linguistic and environmental conditions to examine whether with equivalent exposure some types of words may be, simply put, harder to learn. Such work is ongoing in our lab.

The hypotheses we tested here are not new to this research, and so our evidence supporting these notions (in some cases) corroborates prior work. Perhaps most surprising, then, are the null effects: little evidence for the importance of frequency (among these already frequent words), and little evidence for a broad range of environmental variables that would, a priori, seem reasonable predictors of infants' success in learning. Of course, it is always possible that more sensitive measures would reveal influences that did not emerge here; however, a strength of the present approach is that we are testing learning that takes place in infants' ordinary, daily-life experience.

It is unlikely that any one cause is responsible for infants' later learning of non-nouns than nouns. It is probable that skills underlying pointing and the environmental conditions in which words appear play a role in how easily and at what age words are learned. But a simple frequency-based account does not seem viable for accounting for this difference. Further work is needed to examine the interactions of conceptual, environmental, and social factors in early word-learning of different word types.

Our findings about the developmental timeline of noun and non-noun acquisition suggest that it takes infants nearly as long to learn their first non-nouns as it took to learn their first nouns. Understanding the mechanisms underlying this lag, which we have begun to explore here, requires understanding the intertwined roles of social development, the structure of the world, and the structure of concepts as expressed in natural language. This line of research, in turn, has implications for word-learning, language acquisition, and cognitive development on a much broader scale.

Acknowledgments

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