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Toddlers recognize multiple meanings of polysemous words

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Abstract

Languages often reuse words for related meanings, such as baseball *cap* and bottle *cap*, a phenomenon known as **polysemy**. In English, it is estimated that 40-80% of all words are polysemous, yet little is known about children's early knowledge of polysemous words. In an eye-tracking study with monolingual English-learning 2-year-olds (n=40), we found that participants recognized multiple conventional meanings for polysemous nouns. We further investigated whether toddlers succeeded at this task because they were already familiar with multiple, learned meanings for words, or whether they simply guessed the correct target based on a single or vague meaning. To test this, we also presented participants with novel, related meanings for the same English labels that are not conventional in English, e.g., the meaning "lid" for the label *cap*. The recognition of conventional English meanings (baseball cap, bottle cap) was significantly higher than that of the novel extension meanings (e.g., a lid) for the same label (*cap*). These results show that toddlers' knowledge of polysemy goes beyond a single or vague representation. At the same time, recognition of the novel extended meanings was above chance, indicating that toddlers inferred that a related meaning was the better of the two options. Word learning theories must be further developed to account for these complexities in learning.

Keywords: polysemy; word learning; semantics; development; language acquisition; cognitive development

Introduction

Learning the meaning of a word is recognized to be a challenging task (Quine 1960). Yet arguably, the majority of word learning experiments still underestimate the complexity of the problem. In particular, most experimental work has overlooked or explicitly set aside the fact that up to 80% of frequently used words in English are **polysemous**, in that they can refer to multiple, related meanings, e.g., dog *collar* and shirt *collar*, or baseball *cap*, pen *cap*, and bottle *cap* (Fellbaum 1998; Geeraerts 1993; Lakoff 1987; McCarthy 1997; Rodd, Gaskell, Marslen-Wilson 2002; Zipf 1945). Critically, languages differ in the specifics of how they extend word labels to multiple meanings (Traugott 2014; François 2008; Sweetser, 1990; Murphy, 2004; Heine & Reh, 1984; Malt, 2010). For example, the English word *cap* can to refer to a bottle cap or a hat but not to a lid, while the Spanish word *tapa* can apply to a bottle cap or a lid, but not a hat. This variation suggests that word learning involves learning to recognize multiple conventional meanings for each word.

Sometimes word meanings can be captured by a single vague or underspecified meaning rather than multiple distinct meanings (Falkum 2015; Nunberg 1979; Tuggy 1993). For instance, the English word *aunt* can apply to both a mother's sister or a father's sister. This can be captured without positing two different meanings by simply underspecifying a single meaning that generalizes over both, i.e., a parent's sibling (Langacker 1987). In many cases, however, multiple meanings are required because a vague or underspecified meaning does not suffice. Recent research has found that by the age of four, children are able to learn novel, related meanings if they are related in a systematic way, e.g., *the flour, some flour* (Srinivasan et al., 2019), and even when polysemous meanings relate in unpredictable, convention-based ways, e.g., *coat button, pause button* (Floyd & Goldberg 2020).

It is possible that only older children have had the necessary time and/or have acquired the metalinguistic skills to learn extension patterns or multiple meanings. That is, while children ultimately need to learn polysemy, it may be that early word learning requires the idealized situation commonly assumed by word learning theories, in which each word refers to a single meaning. However, little experimental work has investigated this question, particularly in children younger than three years of age.

To determine if early word learning can support the simultaneous tracking of multiple, related meanings, it is necessary to test young children, while vocabulary and metalinguistic skills remain limited. Therefore, the present study investigates whether or not 2-year-old children are able to recognize polysemous meanings that refer to distinct concepts (e.g., baseball *cap* and pen *cap*, see Table 1 for items), and whether children are able to learn novel meanings that are related but which happen not be labelled by the same word in English.

Monolingual English-speaking children were tested on six words, each with two meanings, in order to evaluate their knowledge of polysemous word meanings. Two critieria determined which words were chosen: their presence in the CHILDES corpus for children under age

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3 (MacWhinney, 2000), as well as whether their translations in another language (Spanish) were associated with a polysemous extension not shared by English (see Table 1). There were two ways in which toddlers could identify a word's multiple, related meanings. They might *recognize* more than a single meaning, having already learned multiple meanings from input. Alternatively, they might be able to *guess* or *infer* additional meanings beyond a single one that had been learned on the basis of semantic similarity and a process of elimination. On trials in the **English meanings** condition, children were exposed to images of conventional word meanings, such as a bottle cap, opposite a distractor (which appeared as a target item on a later trial). On trials in the **Novel extension** condition, children heard the same English labels and prompts (e.g., *Look at the cap!*), but targets were unattested yet plausible polysemous meanings (e.g., a lid). We compared children's performance on the English meaning trials (e.g., baseball cap, bottle cap) to their performance on Novel extension trials which involved unfamiliar but potentially inferable meanings (such as *cap* referring to a lid). On the Novel extension trials, above-chance performance was attributable to an ability to guess an additional meaning, because participants are unlikely to have heard lids referred to *caps*. In order to accurately identify the lid, toddlers would need to activate their knowledge of the familiar meaning(s) of *cap*, and then infer which entity on screen was most similar (i.e., the lid).

Experiment

We investigated whether toddlers could recognize multiple English meanings of 6 nouns (vs. unrelated distractors). We also included Novel extension trials, in which toddlers were prompted with the same English labels but were presented with related meanings for those labels which are unattested in English. If toddlers only succeeded in identifying meanings that are conventional in English, this would indicate that they had learned and could recognize multiple meanings of known words. Toddlers could also have performed equally well in both English meanings and Novel extension conditions. This would imply that they could guess additional possible meanings in real time based on underspecified word knowledge, but could not recognize multiple, stable meanings for polysemous words. That is, the same above-chance performance on both trial types would be evidence that children identify multiple meanings through a process of inference rather than recognition.

We hypothesized a third outcome: children would successfully identify polysemous words on both trial types, but would be more accurate on English meaning trials than on Novel extension trials. This would imply that toddlers are able to guess new meanings of familiar words in real time, but critically, it would imply they track and represent multiple meanings for individual forms in ways that are consistent with their English input.

Method

Participants Forty 24-36-month olds (M = 30.76 months, SD = 2.54 months) with typical hearing and vision development participated in an eye-tracking experiment. All children were monolingual and exclusively exposed to English. Fourteen additional toddlers were recruited but excluded from the sample due to inability to complete calibration (n = 8), parental interference (n = 1), noncompliance (n = 1), trackloss (n = 2; see Results section for criteria), or experimenter error (n = 2). All toddlers were tested in both conditions (English meanings and Novel extension).

Stimuli. The two conventional meanings and the Novel related meaning for each word are provided in Table 1. The Novel meanings were chosen with reference to conventional polysemy in Spanish, a language which our toddlers were unfamiliar with. That is, a single label is used in Mexican Spanish for at least one of the English meanings and the Novel meaning (Spanish word provided in 3rd column). This allowed us to ensure that the Novel meanings were plausible related extensions.

Word lab	Meaning present in both languages	English meaning	Novel meaning (Spanish polyseme in italics)
cap	bottle cap	baseball cap	lid *(tapa)*
sheet	sheet of paper	bed sheet	leaf *(hoja)*
glasses	eyeglasses	drinking glasses	goggles *(gafas)*
collar	shirt collar	dog collar*	necklace*(collar)*
horn	animal horn	musical horn*	croissant*(cuerno)*
balloon	party balloon	hot air balloon*	globe *(globo)*

Table 1: Target polysemous words and meanings. In the Novel extension column, the corresponding Spanish word is in italics. * indicates that the English meaning is additionally present in Spanish, in which case assignment to the 2nd or 3rd column is random.

Procedure All toddlers sat on their caregivers' laps with the exception of one child who sat alone in the chair, approximately 50 cm from the screen in a sound-attenuated room. The caregivers wore an eye mask

which blocked them from seeing what was on screen, preventing a potential source of bias, such as leaning or pointing. The eyetracker was calibrated for each child using a three-point calibration on an EyeLink 1000 Plus. The experiment, which lasted approximately 3 minutes, was created using Experiment Builder software (SR Research, Mississauga, Ontario, Canada) and controlled from a Mac host computer. Toddlers were shown stimuli on a 17-inch monitor while the eye tracker sampled the location of their eye fixations at 500 Hz. On each of 18 test trials, children were prompted with simple English sentences, e.g. *Look at the cap!* while two images were displayed on the screen. There were also four filler trials, which displayed a rainbow circle or pinwheel accompanied by a chime sound.

Word Familiarity Questionnaire To check whether toddlers had been exposed to both conventional meanings of each English word, we asked parents about their child's input. Parents were given a questionnaire which was administered on a laptop after their child completed the study. The questionnaire asked parents to rate how familiar their child was with each of the meanings (e.g. "How familiar is your child with the word *cap* as in *baseball cap*?") on a 5-point scale between "not at all, has never heard it" to "definitely familiar, hears it often."

Results

For all trials, we identified looks to target and distractor images within the 500x500 pixel size of each image, and coded track loss as looks outside of these regions. We excluded trials with greater than 75% track loss. This resulted in the loss of 17.9% of all trials, including 2 subjects entirely, as they had greater than 75% track loss on every trial. Using RStudio, we averaged samples across 100-ms time bins and calculated the proportion looking to target (i.e., the number of samples which were looks to target divided by the sum of samples to target and distractor). We calculated toddlers' proportion of looks to target for each subject in each trial type (English meaning and Novel extension), collapsing across the window of 300-1800 ms following noun onset, as in previous research (Fernald, Marchman & Weisleder, 2013; Lukyanenko & Fisher, 2016; Thorpe & Fernald, 2006).

We predicted that while performance in both English meaning and Novel extension trials would be above chance, performance on English meaning trials should be significantly higher than on Novel extension trials. This was based on the hypothesis that children can learn multiple meanings for labels which are attested in their language, allowing them to better recognize these attested multiple meanings, as compared to the unattested, novel extensions which they must reason about in order to succeed. To evaluate whether performance was reliable, we first entered data into simple one-sample *t*-tests against chance for each condition. Toddlers' mean proportion of looks to target on English meaning trials during the window of interest was significantly above chance (0.5), $t(37) = 7.79$, $p < 0.001$. Toddlers were also able to reliably infer the correct target in the Novel extension trials ($t(37) = 3.30$, $p<0.001$). The final prediction was that, if children at this age are able to learn multiple meanings from their linguistic environment, they should perform significantly better when asked to recognize polysemous meanings from English as compared to meaning extensions which they had never heard before (Novel extension trials). We calculated average proportion of looks to target in each of the two conditions (English meanings and Novel extensions) for each subject and entered it into a paired t-test, which revealed that children looked signpificantly more to target for English meanings than for Novel extensions ($t(37)=2.45$), $p<0.05$). We confirmed these results with a maximal converging mixed effects model, selected by the buildmer package (Voeten 2020), with random slopes and intercepts for subjects. This model revealed that performance in the Novel extensions condition was significantly lower than in the English meanings condition ($\beta = -0.06$, $t = -2.53$, $p = 0.01$). This indicates that our participants could already recognize multiple meanings from prior exposure to English polysemous words, beyond what simply guessing a secondary meaning would allow, as in the Novel extnesions condition (see Figure 2).

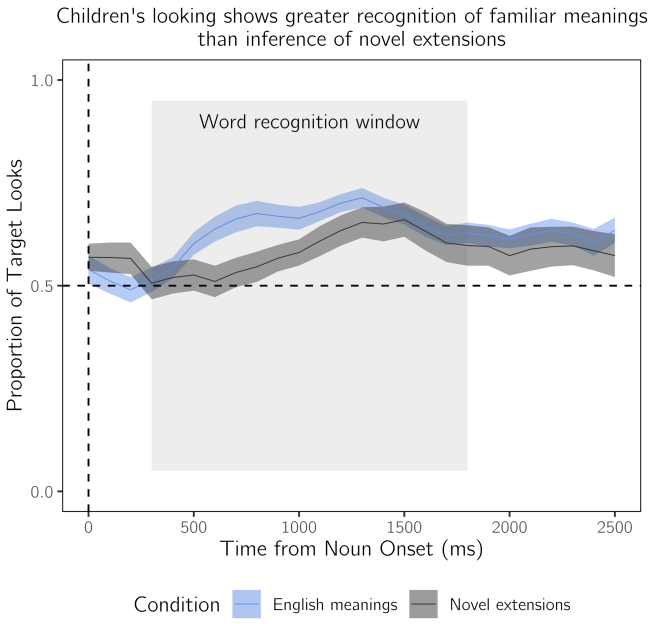


Figure 2: Proportion of looking to target following noun onset (shown at 0ms) in toddlers (n=40) ages 24-36

months on English meaning and Novel extension trials. The window of interest is 300 - 1,800ms following noun onset.

One possible concern is whether toddlers were actually recognizing both meanings of each polysemous noun, or whether instead they used familiarity with one meaning (or a general/underspecified meaning) to succeed in the Novel extension (unfamiliar meaning) condition. To address this, we used parental report to split the English meanings into two groups for each child: higher and lower familiarity. We then compared both to performance on Novel Meaning trials (Figure 2). We excluded trials for which the caregiver estimated equal familiarity for both meanings of the word (34%). In order to simultaneously compare all three trial types, we entered data (again summarized into 100ms time bins per subject per trial within the word recognition time window) into a multilevel model with group (higher-familiarity English, lower-familiarity English, and Novel extension) as the fixed effect along with maximal converging random structure (random intercepts and slopes for subjects). We again found that performance on English meaning trials was higher than Novel extension trials, and though performance on the higher-familiarity trials did not reach significance, it was marginal and consistent with the predicted direction (lower familiarity: $\beta = 0.13$, $t = 4.29$, $p<0.0001$; higher familiarity: $\beta = 0.07$, $t = 1.64$, $p = 0.09$), and another analysis confirmed that there was no difference between the higher- and lower-frequency meanings ($\beta = 0.02$, $t = 1.29$, $p = 0.2$).

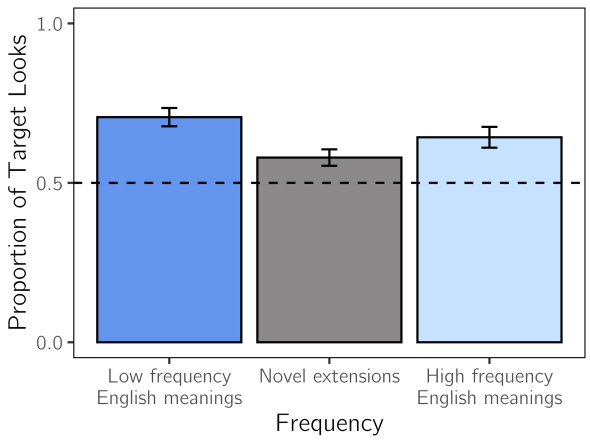


Figure 3: Performance summarized over recognition window for Higher-frequency English meanings, Lower-frequency English meanings, and Novel extensions.

An important possible explanation for lower performance on Novel Meaning trials is that the meanings were preempted in children's vocabulary by other labels (e.g., if the word *lid* was familiar, children may have been slower to look at the lid when prompted with *cap*). If participants performed worse on Novel meaning trials because they faced interference from the preemptive label, more familiarity with the label (lower age of acquisition for that label) should be inversely correlated with their accuracy in looking to target. However, data from age of acquisition norms (Kuperman et al., 2013) show, not only that the AoA for these labels is far later than the age of our participants (Figure 4), but also that the relative AoA of the competing labels does not predict lower performance on these trials: a linear model predicting accurate looking to target on Novel Meaning trials showed no significant negative effect of age of acquisition of the true English labels ($\beta = 0.01$, $t = 0.73$, $p = 0.47$).

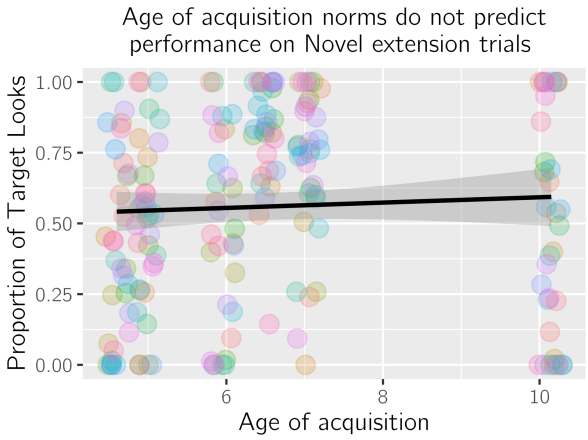


Figure 4: Each dot represents average performance from a child on each of 6 Novel extension trials. If familiarity with a competing label created competition, driving down performance on Novel extension trials, then the later the word is acquired, the lower performance should be. However, this pattern was not borne out in the data, suggesting that possible familiarity with the correct English label in Novel extension trials is not responsible for the lower performance.

Discussion

To summarize, we investigated whether toddlers can recognize multiple meanings on the basis of their input, and whether they are able to guess new related meanings upon seeing possible extensions. We found evidence for both (1) experience-driven recognition of polysemous meanings in two-year-old children in the English meanings condition and (2) guessing or inference of meanings in the Novel extension condition. We tested monolingual English-learning toddlers on real polysemous English words, which happen to generalize differently in an unfamiliar language (Spanish). Results confirmed that children showed above-chance accuracy in identifying the two English meanings of the word *and* a tertiary meaning that is novel in English (but that exists in Spanish). Critically, performance on English meaning trials (containing English meanings, which our participants have been exposed to) was higher than on Novel extension trials (similar meanings, which our participants would have to guess). This provides evidence that toddlers have already learned multiple meanings for the polysemous words we tested, rather than simply guessing conventional meanings on the basis of a single stored meaning or a generalization.

An understanding of the ubiquity of polysemy and the early age at which children learn polysemous meanings requires a new perspective on word learning. Even very young learners are able to encode a *network* of related meanings. This network perspective does not require children to delete, dampen, or suppress additional meanings of a word, as in some existing theories (e.g., Stevens et al., 2016). Instead, when an additional meaning is encountered that is related to an existing representation of a word's meaning, a new, if tentative and fragile, meaning can be learned. Our results demonstrate that, from early in development, there are mappings between a word form and *meanings,* and that a word can be flexibly extended to a new meaning on the basis of its relationship to prior meanings. If English lacked a word, *lid*, toddlers may at least be ready to call it a *cap*. However, we also find that toddlers were tracking the polysemous meanings in their input, as evidenced by the stronger performance on English meanings trials (vs. Novel extension trials). This suggests that toddlers do not simply rely on a vague or underspecified representation to extend labels to any meaning with a sufficiently strong similarity.

These results take an important step in understanding how the rich and varied meanings of 40-80% of real words are learned. Toddlers' performance on English meaning trials provides evidence that even 2 ½ year-olds already represent and recognize multiple meanings for a single form. At the same time, our findings demonstrate that children are capable of flexibly inferring an additional potential meaning of a familiar word on the basis of the relationship between the new and familiar meanings. Over time, this flexible capacity to use existing meanings to infer new, polysemous extensions may be crucial in vocabulary development more broadly, as older children, adolescents, and even adults must keep pace with special, technical, innovative, and slang extensions for words and meanings they may have been familiar with since age 2 ½.

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