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Journal

Proceedings of the Annual Meeting of the Cognitive Science Society, 41(0)

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Publication Date

2019

Peer reviewed

Children, more than adults, rely on similarity to access multiple meanings of words

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Abstract

Past research has shown that adults can access multiple meanings for a word, but little work has examined how children process multiple meanings. We tested 48 4- to 7-year-old children and 48 adults in a touchscreen picture recognition task. Two meanings of the same word were displayed on successive trials, which varied according to whether the 2 meanings were unrelated (homonyms), related (polysemes), or repeated (same-meaning). Adults identified the second meaning more quickly than the first in all conditions and to the same extent. Children, however, identified the second meaning more quickly only on polysemy and same-meaning trials. This difference suggests that children are less capable of co-activating unrelated meanings, which raises the possibility that children must *learn* to do so over development. Despite the ubiquity of polysemy in language, our work is the first to show that children's processing of word representations is organized by similarity.

Keywords: polysemy, lexical processing, development, cognitive development, ambiguity

Introduction

Upon hearing a word like *bat,* which can refer to a flying mammal or a wooden stick, adults unconsciously activate both meanings, at least for a brief period when there is no biasing context and both meanings are equally frequent (Brocher, Koenig, Mauner, & Foraker, 2017; Onifer & Swinney, 1981; Swinney, 1979; Zwitserlood, 1989). This intriguing finding was initially used to argue for "exhaustive" lexical access during an early modular stage of processing (Fodor, 1985; Swinney, Plather, & Love 2000; but cf. Armstrong & Plaut, 2016). At the same time, a large and growing body of evidence indicates that people take advantage of communicative contexts to predict interpretation from the earliest stages of comprehension (Kintsch, 1988; Rubio-Fernandez, Mollica & Jara-Ettinger, 2018; Tanenhaus, Spivey-Knowlton, Eberhard, & Sedivy, 1995; Yip & Zhai, 2018).

Due to the tension between evidence for exhaustive lexical access, on the one hand, and early contextual influences on the other, much work has varied task demands, relative frequencies of the two meanings, interstimulus intervals and degrees of contextual bias in order to predict the conditions under which multiple meanings of a word are accessed or recognized. Selective, rather than exhaustive, activation has been found to occur when the context is strongly biased toward a more frequent meaning (Meyer & Federmeier 2007; Sereno, Brewer, & O'Donnell 2003; Sereno, Pacht, & Rayner 1992; Simpson, 1981; Marslen-Wilson & Welsh, 1978).

Another factor that plays a role in lexical access and recognition is the degree of relatedness among a word's meanings. That is, there is a gradient distinction between meanings that are **homonymous** or unrelated to one another (e.g., a flying bat vs. baseball bat), and **polysemous** meanings, which are semantically related to varying degrees (Tuggy, 1993). For instance, the word *network* can be used to refer to a TV channel, a group of colleagues, or a graph (Lau, Cook, McCarthy, Gella, & Baldwin, 2014). While these meanings are distinct, they are to some extent related.

Relationships among meanings are relevant to the so-called "ambiguity advantage": Adults have been found to respond faster in lexical decision tasks to a meaning for an ambiguous word compared to a word with a single meaning (Jastrzembski, 1981; Rubenstein, Garfield, & Millikan, 1970). This effect has sometimes been found to be stronger for words with multiple *related* senses (Klepousniotou & Baum, 2007; Rodd, Gaskell, & Marslen-Wilson, 2002). In fact, Armstrong & Plaut (2008) and Rodd, Gaskell & Marslen-Wilson (2002) found that homonymous senses can *slow down* lexical access due to competition under higher of levels task difficulty (see also Brocher et al. 2016). Other evidence that ambiguous words compete in a way that polysemous meanings may not comes from an ERP study by Klepousniotou et al. (2012), who found a greater N400 was evoked by a less dominant meaning of homonymous words in a lexical-decision task, but no increase in the N400 for the less dominant meaning of polysemous words. On the other hand, Brocher et al.

(2017) found that both homonymous and polysemous meanings compete when words were equally biased toward both meanings. Thus, the work on access and recognition of ambiguous words has revealed a complicated picture, indicating that frequency, degree of contextual bias, timing, task demands, and semantic relatedness each influence lexical activation (Tabossi & Sbisá, 2001).

In order to clarify key influences on lexical access, the current work compares the behavior of children and adults on an identical task. A word repetition paradigm is used to detect whether witnessing one meaning of a word primes a second meaning of the word. Specifically, in a 2-alternative forced-choice picture identification task, adults and 4- to 7-year-old children were exposed to a word on each trial, and had to select which of two images corresponded to that word's meaning. On the immediately following trial, the same word was presented again. Across these key trials, the degree of relatedness between the first and second target meanings of words was systematically varied.

Of interest was whether reaction times decreased between the identification of the first and second meanings of words. If we do see priming effects for both homonymous and polysemous word meanings, it would be evidence that the two meanings are linked as is required for exhaustive access. This is expected in adults, at least if the time between trials is sufficiently brief. At longer inter-stimulus intervals (ISIs), we might expect the first meaning to interfere with the second meaning, which would predict an increase in reaction times to the second meaning.

If both children and adults display the same increase or decrease in reaction time when identifying the second meanings of ambiguous words, it would suggest that key aspects of lexical access are a developmentally stable. We know that children, like adults, comprehend language incrementally (Swingley, Pinto, and Fernald 1999; Fernald, Swingley, & Pinto 2001). Also, children, like adults, are subject to priming and plausibility effects when they need to disambiguate an intended meaning (Rabagliati, Pylkkänen & Marcus 2013). But we don't yet know whether children and adults will behave alike or differently under the identical task demands that require them to identify two familiar meanings of words in succession.

A significant difference between children and adults' behavior could shed light on the mechanisms involved in lexical access or on the way that lexical representations develop. If children show *stronger* evidence of exhaustive lexical access for ambiguous and polysemous words, it would be consistent with proposals that view selective access as requiring cognitive control (Balota, Cortese, & Wenke, 2001),

since children's cognitive control is less well developed than adults (Bunge, et al. 2002). On the other hand, if children show *weaker* evidence of accessing multiple familiar meanings of words, it would suggest that they represent individual meanings more independently than adults do. This would suggest that word learning involves both acquisition of item-specific knowledge for each meaning *and* a protracted trajectory for linking among each word's meanings. This would indicate that children have to *learn* to co-activate multiple meanings based on experience, with potentially different trajectories for related versus unrelated meanings.

Some past work has investigated how children over the age of 8 activate the intended meaning of homonymous words, by focusing on cases of homonymy in which one meaning was dominant over others (Marmurek & Rossi, 1993; Simpson & Forster, 1986; Simpson et al. 1994). This research found relatively consistent results: older children are better at using contextual cues to activate less frequent homonymous meanings than younger children. Booth, Harasaki & Burman (2006) extended this work by comparing effects of sentence-level primes vs. lexical primes and found a more complex picture. Younger children or less skilled readers were less likely than older children to use a preceding lexeme to facilitate activation of a less-frequent homonymous meaning, while older children/high skilled readers facilitated and inhibited homonymous meanings using sentence-level information (Booth, Harasaki & Burman 2006).

The present work uses participants' reaction times to investigate how words with multiple meanings are processed in children and adults, when both meanings need to be identified in succession. By comparing performance on homonymous and polysemous meanings with a baseline condition, we can determine whether greater semantic similarity supports the co-activation of lexical representations. This would be evident if participants are faster to recognize the second meanings of polysemous words than homonymous words.

In the experiments reported below, we children and adults were presented with each of 18 target words twice in immediate succession: 6 words were paired with 2 unrelated meanings (homonymy condition); 6 words with 2 related meanings (polysemy condition); and 6 words were presented with different images which represented the same meaning (same-meaning trials). We also included 12 singleton filler trials to reduce the extent to which participants could rely on a repetition expectation to predict what they might hear and see next. For homonymous and polysemous trials, each word was presented with one target meaning on first exposure and a different target meaning on the second

Trial type	Word
6 same-sense repeated	*bowl, treehouse, ring, key, lantern, shelf, trunk*
6 polysemous senses	*cap, buttons, cone, glasses, shower, step*
6 homonymous meanings	*bow, ruler, pitcher, bat, calf, nail*
12 singletons	*basket, cake, crayon, feather, hood, lemon, ivy, log, playground, punch, wagon, bark*

Table 1: Items

exposure, with the order of target meanings counterbalanced across participants and sides of presentation randomized. Repeat same-meaning trials served as a window into baseline priming effects. The main prediction was that, if children's word representations are organized by similarity, they may be able to activate a second, distinct meaning quickly in the case of polysemy. In the case of homonymy, however, where semantic similarity is not available to help co-activate other meanings which share the same label, accessing both meanings should be slower. In the same paradigm, we also predict that adults should be able to activate multiple meanings equally well in both polysemy and homonymy, consistent both with prior findings and with the idea that we learn to access unrelated meanings, at least in certain contexts, through experience. Finally, adult participation allows us to verify that it is, in fact, possible for our paradigm and chosen items to elicit priming of unrelated meanings.

Method

Participants
48 adult participants [recruited online] and 48 children ages 4.5-7 (M=5.89; SD= 0.62). Children were given a book of their choosing and a small prize as thank-you gifts.

Procedure

Two initial training trials provided feedback if participants answered incorrectly, or took longer than 4500ms, ensuring that they understood the goal of the task was to answer accurately and quickly (see Figure 1). Between each trial (including between training trials), a pulsing blue dot appeared that participants had to press to advance to the next trial. This was to ensure that participants' hand positions were centered. Each participant responded to 48 trials including 6 homonym pairs (12 trials), 6 polysemy pairs (12 trials), 6 same-sense pairs (12 trials) and 12 singleton filler trials.

The design was 3 (condition) x 2 (1st or 2nd encountered meaning), within-subjects. We tested two groups (adults and children). Before each trial began, participants had to place their pointer finger on a dot in the middle of the screen. Overall order of stimuli (or stimuli pairs) from each of the four trial types (polysemy, homonymy, same-sense pairs, and fillers) was randomized across participants. The experiment was conducted on an iPad that recordedd participants' accuracy and reaction times to target. The key dependent measure was the difference in reaction time from the identification of first and second senses of words in the three experimental conditions.

On each trial, participants heard a word and had to choose the target image representing its meaning from a distractor image presented on the opposite side of the screen (screen side counterbalanced). For homonymous, polysemous and same-sense trials, the same word was repeated twice in succession with images corresponding to a second unrelated, related, or same sense, respectively.

The order of presentation within each word's pair of meanings as well as the order of trials in the experiment was counterbalanced across participants to avoid possible confounds of meaning familiarity or distractor salience. Moreover, since participants witnessed both ambiguous and polysemous trials, any significant difference in familiarity between the ambiguous items and the polysemous items should be evident in a comparison of response times to the first presentations across these conditions, which we also include as part of our analyses.
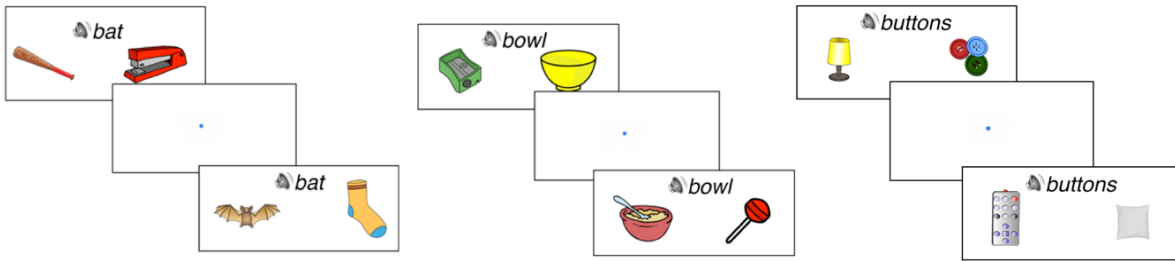
Figure 1: Representation of the experimental stimuli in the homonymy (*bat*), repeat (*bowl*) and polysemy (*buttons*) conditions.

Results

The data were log-transformed and analyzed using a multilevel linear model with condition (homonymy vs. polysemy vs. same meaning) and first vs. second meaning of each pair as fixed effects, and maximal converging random effect structure: here, random intercepts and slopes for subjects, presentation order, and items: Reaction Time ~ FirstOrSecond * Condition + (1 + FirstOrSecond | subject) +

(1 + Condition | order) + (1 + FirstOrSecond | item).

Adults recognized the second sense of words more quickly after the initial exposure to that word, and facilitation was equally strong for unrelated (homonymy), related (polysemy), and same senses: (main effect of secondary sense response, β = -0.15515, p = 0.00129, with no significant interactions by condition (Figure 2).

Children, on the other hand, did not show significant facilitation when selecting the second sense of homonymous words, but did for polysemous words (β = -0.12798, p = 0.0333) and repeated meanings (β = -0.200424, p = 0.0122) (Figure 2). The difference between facilitation for polysemous and same-sense trials was not significantly different (β = -0.08638, p = 0.2189), suggesting that related senses were primed by one another to almost the same degree as a second instance of the same sense. Unlike results for adults, there was not even a numerical decrease in reaction time when the second presentation of a word was paired with an unrelated (homonymous) sense.

A concern worth addressing is whether children were less familiar with the meanings of the homonymous words. Indeed, we cannot expect facilitation for a second meaning if only one meaning was familiar to children. To ensure this did not account for our results, we excluded any trials in which children or adults had answered incorrectly on either trial for all analyses reported thus far. This issue can be further addressed by a comparison of accuracy in the polysemy vs. homonymy condition. We found that their accuracy was not significantly lower in homonymy than polysemy in a linear model with maximal converging random slopes and intercepts for subject and order (β -0.03, t= -1.410, p= 0.172), and neither were their reaction times slower to the first exposure in homonymy as compared to polysemy (β= 0.075, t= 0.844, p= 0.405). Since the order of presentation of the two meanings was counterbalanced across participants for each word, we can conclude that children were equally familiar with the senses of the homonymous, polysemous, and same-sense meanings, as intended.

Limitations

In our task, answers appeared on either side of the screen. In order to control for hand/mouse position effects, intervals between each trial required participants to press a central fixation, and the experiment did not advance to the next trial until participants did so. Because of this, inter-stimulus intervals (ISIs) were not controlled, and instead were determined by how long the participant took to press the central fixation. Importantly, prior work has shown that second senses of homonymous words become suppressed as quickly as a few syllables downstream, and early work in semantic priming did not reveal effects for priming across more than one intervening trial (Joordens & Besner, 1992), suggesting that we should not expect to see priming in the case of longer inter-stimulus intervals. Therefore, the ISIs observed in our experiment warrant further investigation.

To address this concern, we report average ISIs for the two groups, as well as a comparison of the two (adults: M = 1961ms, SD = 5196ms, children: M = 1147ms, SD = 701ms). We then entered log-transformed ISI lengths into a mixed effect model with age group (child vs. adult) as the fixed effect and maximal converging random structure including a random intercept and slope for subject and intercept for trial number (order), revealing no effect of the age group (child): β =-0.09643, p = 0.4). So, while average ISIs were longer than those used in traditional priming experiments, it is unlikely that the difference between
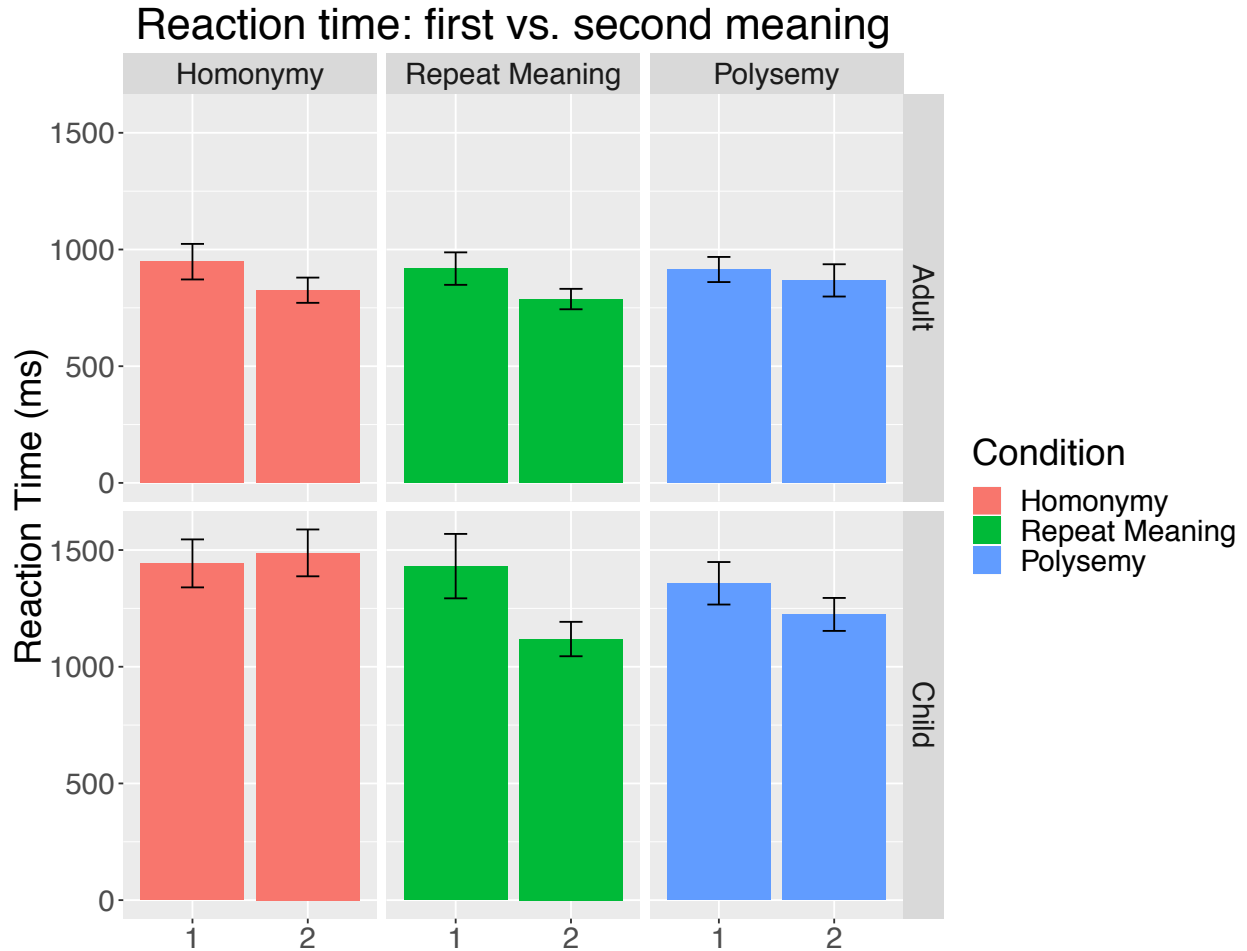
Figure 2: Raw reaction time data (analyses were done on log-transformed data). Error bars represent bootstrapped 95% confidence intervals.

ISIs is what drove our children to perform differently than adults. Past work with children has also used longer ISIs with children, such as 1,000ms (Booth, Harasaki & Burman, 2006), as compared to ISIs in adult lexical decision tasks.

Consistent with our results, Armstrong & Plaut (2016) emphasize that the timing of adult participants' suppression of irrelevant senses varies by task difficulty as well as latencies. Later work on semantic priming has in fact shown evidence for longer-term priming, across as many as 8 intervening items (Joordens & Becker, 1997). The implication of this work on our predictions instead suggests that participants may be expected to benefit from priming over longer periods of time.

Discussion and Conclusion

This investigation is the first, to our knowledge, to compare children's and adults' co-activation of related

word meanings. Prior work has found that under certain conditions, adults access more than one meaning of a word, at least for a short period of time, unless one meaning is both more frequent and anticipated within the context. In the current study, the facilitation evident in adults' response times to second meanings demonstrates that, regardless of relatedness, adults are capable of accessing two meanings simultaneously or are at least able to anticipate a second meaning. To emphasize, adults displayed faster reaction times to a second meaning even when that meaning was entirely unrelated to the first (e.g., baseball *bat* following mammal *bat*).

Children, on the other hand, showed facilitation only when the second meaning was related or identical to the first. They showed no evidence that the recognition of one sense of a word facilitated the recognition of an unrelated meaning of that word. We addressed the possibility that children were less familiar with the meanings of the homonyms by observing that their

accuracy and response times on the first exposure of each word-type were not different. The current findings thus indicate that children's representations of a word's two unrelated meanings may not be linked together in the same way that adults' are. Instead, while children showed a facilitation effect in the recognition of a second *related* meaning, unrelated meanings were recognized as slowly as completely new words.

Given this, it may be that children must *learn* to activate multiple homonymous meanings across time. Intuitively, this makes sense: a spreading of activation between the mental representation of "bottle cap" and of "pen cap" may be a natural consequence of shared or similar features, while the representations of "baseball bat" and "flying bat" are likely to overlap very little, if at all. Yet again, ultimately speakers do eventually learn to access both meanings, at least or a brief period under certain task demands, as demonstrated by evidence co-activation both in our task and in previous work with adults (Brocher, Koenig, Mauner, & Foraker, 2017; Onifer & Swinney, 1981; Swinney, 1979; Zwitserlood, 1989). This raises the question as to *why* and *how* the ability to access unrelated meanings of a word develops.

Insofar as listeners cannot reliably predict which meaning of a word is intended, a degree of flexibility is advantageous in language processing to avoid being essentially garden-pathed by an unintended meaning. Indeed this type of flexibility may be advantageous in language learning as well, insofar as a more efficient ability to update predictions has been found to correlate with larger vocabulary size (Reuter, Emberson, Romberg, & Lew-Williams, 2018).

We can only speculate as to exactly *how* this ability to access secondary unrelated meanings of words increases after the age of 7. But presumably either links between two distinct representations are created or the representations of homonymous meanings come to share greater overlap. Stronger links between unrelated senses of homonymous words may be formed as a result of repeated misinterpretations that require learners to access an alternative sense as quickly as possible for the sake of comprehension. Alternatively, it is possible that links between meanings of homonymous words are formed on the basis of more explicit, metalinguistic knowledge. It is possible that co-activation is facilitated simply by an awareness that labels can refer to multiple meanings. On this interpretation, the information that the word *bat* as two unrelated meanings would be similar to learning that the word, *aunt* can be pronounced in two distinct ways.

A non-mutually exclusive possibility is that co-activation may be encouraged by learning to read. Specifically, a shared written form in combination with a shared auditory label can be expected lead to an increase in representational overlap between two meanings of a homonymous word. This would support the idea that representational overlap is required for co-activation. Future work can test this by comparing words that vary in whether they are spelled alike compared to words that are not (*bat vs. bat; flower vs. flour*). If the link between unrelated meanings is mediated via a shared visual form, we expect facilitation for homonyms that share the same spelling but not for homonyms that are spelled distinctly.

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