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Word learning in linguistic context: Processing and memory effects

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ABSTRACT

During language acquisition, children exploit syntactic cues within sentences to learn the meanings of words. Yet, it remains unknown how this strategy develops alongside an ability to access cues during real-time language comprehension. This study investigates how on-line sensitivity to syntactic cues impacts off-line interpretation and recall of word meanings. Adults and 5-year-olds heard novel words embedded in sentences that were (1) consistent with an agent-first bias (e.g., "*The blicket will be eating the seal*" → "*the blicket*" is an agent), (2) required revision of this bias (e.g., "*The blicket will be eaten by the seal*" → "*the blicket*" is a theme), or (3) weakened this bias through a familiar NP1 (e.g., "*The seal will be eating/eaten by the blicket*" → "*the seal*" is an agent or theme). Across both ages, eye-movements during sentences revealed decreased sensitivity to syntactic cues in contexts that required syntactic revision. In children, the magnitude of on-line sensitivity was positively associated with the accuracy of learning after the sentence. Parsing challenges during the word-learning task also negatively impacted children's later memory for word meanings during a recall task. Altogether, these results suggest that real-time demands impact word learning, through interpretive failures and memory interference.

1. Introduction

During word learning, children exploit predictable relationships between linguistic forms and meaning, a strategy known as syntactic bootstrapping (Fisher, Gertner, Scott, & Yuan, 2010; Gleitman, 1990). Successful bootstrapping requires that learners not only have relevant syntactic knowledge (e.g., active-passive alternation), but also access this information efficiently during real-time comprehension (e.g., perceiving "*eating*" in (1a) as different from "*eaten by*" in (1b), assigning appropriate roles to arguments, predicting likely referents of novel words).

(1) a. Active: The blicket will be quickly eating the seal
b. Passive: The blicket will be quickly eaten by the seal

However, little is known about how syntactic bootstrapping operates alongside a developing system for syntactic processing. It is often assumed that children learn by interpreting utterances in an adult-like manner (Fisher et al., 2010; Waxman & Booth, 2003). Yet, prior research reveals notable ways in which syntactic cues are often ignored during real-time comprehension (Choi & Trueswell, 2010; Huang, Zheng, Meng, & Snedeker, 2013; Hurewitz, Brown-Schmidt, Thorpe, Gleitman, & Trueswell, 2000; Omaki, Davidson-White, Goro, Lidz, & Phillips, 2014; Trueswell, Sekerina, Hill, & Logrip, 1999; Weighall, 2008). What do children learn in these contexts? How do limitations of syntactic parsing impact the informativity of syntactic cues?

The current study explores these questions by isolating the effects of syntactic processing on word learning in 5-year-old children. We reasoned that if syntactic bootstrapping depends on a developing system for accessing syntactic cues within utterances, then word learning should be challenging when these cues are hidden by real-time demands and more successful when these demands are removed. Parsing effects should also generate systematic relationships between on-line sensitivity to syntactic cues, off-line interpretation of words, and memory for meanings. In the remainder of the Introduction, we will briefly summarize prior research on children's use of syntactic cues during word learning and sentence comprehension. Next, we will discuss recent work suggesting that real-time comprehension has cascading impacts on language learning. Finally, we will consider why comprehension of passives may be particularly informative and sketch out how word-learning mechanisms will be isolated in the current study.

1.1. Syntactic cues in word learning and sentence comprehension

Children's use of syntactic cues is central to two parallel literatures, focusing on distinct time scales. In the field of language

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acquisition, previous research has explored how children learn the meanings of words via syntactic cues in sentences (Brown, 1957; Fisher et al., 2010; Gleitman, 1990; Waxman & Booth, 2003). For example, 3- to 5-year-olds' knowledge of the mass-count distinction generates inferences that "*a blicket*" refers to an individuated object (e.g., rock-like item) while "*some blicket*" refers to a less-coherent substance (e.g., toothpaste-like item) (Barner & Snedeker, 2005; Bloom & Kelemen, 1995; Brown, 1957). Similarly, knowing the transitivity distinction allows 2-year-olds to infer that "*gorping*" refers to a causative event in a transitive structure (e.g., "*The rabbit is gorping the duck*" → a rabbit pushing a duck) but a self-propelled event in an intransitive one (e.g., "*The rabbit and duck are gorping*" → a rabbit and a duck swinging their arms) (Arunachalam & Waxman, 2010; Naigles, 1990; Yuan & Fisher, 2009). On the whole, research in language acquisition has focused on year-to-year differences that emerge during development (Fisher et al., 2010; Waxman & Booth, 2003). When do children first engage in syntactic bootstrapping? What cues do they rely on when they do so?

In contrast, more recent work has focused on how children interpret syntactic cues on a millisecond time scale (Omaki & Lidz, 2015; Snedeker & Huang, 2015; Trueswell & Gleitman, 2004). These studies have highlighted two characteristics of developmental sentence processing. First, like adults, children recruit reliable syntactic cues to incrementally predict who did what to whom (Choi & Trueswell, 2010; Huang et al., 2013; Snedeker & Trueswell, 2004; Snedeker & Yuan, 2008). For example, 5-year-olds infer that ambiguous prepositional phrases (PPs) refer to instruments following instrument-biased verbs (e.g., "*Hit the frog with the stick*" → Hit using the stick) and patients following modifier-biased verbs (e.g., "*Choose the frog with the stick*" → The frog that's holding the stick) (Snedeker & Trueswell, 2004; Snedeker & Yuan, 2008). However, unlike adults, children often ignore syntactic cues that conflict with an initial misinterpretation (Choi & Trueswell, 2010; Huang et al., 2013; Hurewitz et al., 2000; Omaki et al., 2014; Trueswell et al., 1999; Weighall, 2008). Trueswell et al. (1999) found that when presented with a temporarily ambiguous sentence like "*Put the frog on the napkin into the box*" adults and 5-year-olds initially look towards a plausible destination (e.g., an empty napkin), suggesting that both age groups misanalyze PP1 as a location for the verb. Following the onset of PP2, adults realize that PP1 is in fact a modifier that describes the target referent (e.g., frog *that's* on the napkin). Children, on the other hand, often ignore this late cue and generate incorrect actions on 60% of trials (e.g., putting the frog on a napkin, before moving it to the box).

Difficulties with syntactic revision occur despite the fact that children correctly interpret ambiguous (e.g., "*Choose the frog with the fork,*" Snedeker & Trueswell, 2004; Snedeker & Yuan, 2008) and unambiguous modifiers (e.g., "*Put the frog that's on the napkin into the box,*" Hurewitz et al., 2000; Trueswell et al., 1999) and produce these structures to avoid referential ambiguity (Hurewitz et al., 2000). Taken together, prior findings suggest that even when children have relevant syntactic knowledge, they may not always effectively access it during comprehension. Importantly, parsing challenges have implications for learning since children often encounter complex constructions in their input, e.g., multiclause sentences, non-canonical word orders (Huttenlocher, Vasilyeva, Cymerman, & Levine, 2002; Huttenlocher, Vasilyeva, Waterfall, Vevea, & Hedges, 2007; Huttenlocher, Waterfall, Vasilyeva, Vevea, & Hedges, 2010; Newport, Gleitman, & Gleitman, 1977). Are these utterances informative for word learning? If so, how do children exploit relevant syntactic cues in their input?

1.2. Does syntactic processing impact language learning?

Indeed, recent studies suggest that developmental challenges with syntactic revision have cascading impacts on language learning. For example, causative verbal morphology reliably marks causal events in verb-final languages like Kannada and verb-initial languages like Tagalog. Nevertheless, when comprehension was assessed, 3- to 4-year-old learners of Kannada generated causative actions only 11% of the time (Lidz, Gleitman, & Gleitman, 2003) while learners of Tagalog did so 36% of the time (Trueswell, Kaufman, Hafri, & Lidz, 2012). This asymmetry suggests that cues that occur earlier in sentences (guiding initial interpretation) are easier to acquire compared to those that occur later in sentences (revising initial interpretation).

To test this hypothesis, Pozzan and Trueswell (2015) manipulated morpheme location within an artificial language task. English-speaking adults were taught that the marker "*ka*" was associated with an instrument interpretation in both verb-initial and verb-final versions of sentences like (2), i.e., to bounce the dolphin using the clothespin.

(2)	a. Verb-initial language:	Zumpi-ka fami nunu	(Bounce-ka dolphin clothespin)
	b. Verb-final language:	Nunu fami zumpi-ka	(Clothespin dolphin bounce-ka)

Over a 3-day period, learners of verb-initial languages demonstrated more successful learning compared to their verb-final counterparts. Following the onset of the marker, they generated more eye-movements to correct referents and revealed greater accuracy in final comprehension. Importantly, they also produced more accurate descriptions, suggesting that early cues facilitated the mastery of grammatical knowledge and not simply the ease of real-time comprehension. Finally, adults were asked to infer verb meanings based on the sentential and referential context, e.g., learning that "*zumpi*" in (2) means bounce. Once again, learners of verb-initial languages outperformed their verb-final counterparts. These findings suggest that real-time parsing can alter the informativity of syntactic cues, influencing the trajectory of learning.

Similar effects were also found in recent work on infant word learning (Lidz, White, & Baier, submitted for publication). Using a preferential-looking paradigm, 16-, 19-, and 26-month-olds were familiarized to sentences like (3), paired with a scene of a woman pushing a truck using a block.

(3)	a. Direct-object:	She's pushing the tiv
	b. Prepositional-object:	She's pushing with the tiv

During the test phase, infants saw a truck (patient) and a block (instrument) and were asked, "*Where's the tiv?*" Sixteen- and 28-month-olds looked to a truck following (3a) and a block following (3b), suggesting that they distinguished the syntactic contexts and generated correct referential expectations on this basis. Curiously, 19-month-olds consistently preferred patients, even when they heard the preposition in (3b). Lidz and colleagues (under review) argued that these errors reflect a period in which subcategorization frequencies of verbs strongly favor direct objects. This bias, paired with developmental difficulties with syntactic revision, lead 19-month-olds to maintain a direct-object interpretation, even after encountering conflicting cues.

Nevertheless, prior work leaves open two key questions. First, it remains unclear the extent to which unsuccessful learning is *caused* by insensitivity to late-emerging syntactic cues. Developmental research typically relies on the preferential-