# Syntactic Bootstrapping

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## Key Points

- Syntax guides children's word learning, particularly when the extralinguistic context is less informative
- Syntactic bootstrapping depends on links between syntax and semantics, which allow learners to use syntactic cues to make inferences about word meanings
- Experimental evidence indicates that children can draw on syntax during word learning from the second year of life
- For action verbs, syntax can indicate the intended construal of an event, which points learners toward the word meaning
- The syntactic distribution of propositional attitude verbs can help learners identify them and make the cut between belief and desire verbs

### Abstract

In syntactic bootstrapping, children draw on syntactic information to constrain their hypotheses about word meanings. We review evidence for syntactic bootstrapping, focusing primarily on the acquisition of verb meanings. For verbs describing physical actions, children can use the argument structure from event descriptions to zero in on the verb meaning. For attitude verbs, which refer to mental states, the syntactic distribution is informative about their semantics. By making use of systematic syntax-semantics correspondences, syntactic bootstrapping provides a foothold for word learning when cues from the physical world are underinformative.

## Introduction

The number of potential meanings for a novel word is vast and yet children seem to zero in on the correct meanings of new words with little error. Syntactic information serves as an important information source. Words with similar meanings occur in similar syntactic environments. If some of these correlations between meaning and distribution have a principled source, then learners can use a word's syntactic distribution to constrain their hypotheses about its meaning. Here, we review evidence for this syntactic bootstrapping procedure.

## The Word-Learning Problem

Children acquiring their first language must learn an enormous number of words. In some cases, circumstances conspire for children to experience referential "gems" such that a word co-occurs with a cue from the extralinguistic context, such as an adult pointing to the referent (Gleitman & Trueswell, 2020). Even under these conditions, children must constrain their hypotheses about word meanings, to avoid, for instance, assigning the word *doggy* a meaning such as "dog or elephant" or "has a tail" (Chomsky, 1959; Quine, 1960). But for many words, the problem is even more dire, as there is little to no information available in the physical world that can provide clues to the word's meaning. For example, how can children isolate the meaning of *buy* if every instance of "buying" they observe is also a "selling?" How can children figure out that *want* and *think* refer to mental states, when those mental states will never be directly observable?

The magnitude of the word-learning problem was illustrated in a set of experiments by Gillette et al. (1999) using the Human Simulation Paradigm, in which adult participants were presented with silent videos of parent-children interactions and cued with

a beep when the parent uttered a target word. Despite seeing six videos of the same word being used in different contexts, the adult participants—who presumably also bring to bear more mature cognitive capacities than infants—were remarkably inaccurate, guessing nouns correctly 45% of the time and verbs only 15% of the time (for similar results from children, see Piccin and Waxman (2007)). These results suggest that the extralinguistic context does not contain adequate cues to the meanings of many words.

What other information, then, can children bring to bear on the task of word learning? A growing body of evidence suggests that children are able to make use of their language's syntax—that is, to engage in *syntactic bootstrapping* (Gleitman, 1990; Gleitman et al., 2005; Landau & Gleitman, 1985). This proposal hinges on the observation that there is a systematic correspondence between a language's syntax and semantics (Fisher et al., 1991; Jackendoff, 1978). If children are aware of this correspondence, they can use the syntax to provide clues about the semantics of the word. For example, if a child observes that a verb takes a clausal complement (as in *She thinks* [*he left already*]), she can infer that the verb's meaning has to do with mental states. The syntax is predicted to be especially useful for words that are unlikely to occur with informative cues from other sources, such as the extralinguistic context and co-occurring words (Snedeker & Gleitman, 2004).

In line with the syntactic bootstrapping account, experimental findings indicate that children are capable of using syntactic information during word learning as early as the second year of life. In this article, we will focus in particular on verb learning—first, verbs referring to physical actions, and second, mental state verbs—since research has concentrated most on these areas. This will also allow us to distinguish two related notions of syntactic bootstrapping: (a) the way that syntax can interact with the extralinguistic context to fix a perspective on a scene, constraining a word's hypothesized meanings, and (b) the idea that information contained in a word's overall syntactic distribution can clue a learner in to the semantic field it occupies.

## Event Descriptions

For verbs that typically describe physical actions, such as *push* and *drink*, children may still be able to turn to the physical world to provide some clues about their meanings. For example, a parent might say "The dog is chasing the cat!" as an actual chasing event is occurring. In this case, the extralinguistic context and the event description are jointly informative about the meaning of *chasing*. By 14 months, children already expect that a verb will refer to an event concept, and not, for instance, an object concept (He & Lidz, 2017). However, even once a child has isolated the verb (here, *chasing*) and matched it to an event taking place in the world, it is still not sufficient to fully determine the word's meaning. The reason for this is that a verb could describe the physical scene just as well if it referred to the action of chasing (which the girl is doing) or the action of fleeing (which the dog is doing), or even the action of running or exercising (which both are doing). In other words, to make use of the event description, a child needs to know what perspective the speaker is taking on the scene—who is the agent (doer) of the action and who is the patient (affectee)? These participant roles, often called thematic roles, are semantic properties of the event, and they exhibit a systematic correspondence with the syntax in the form of the verb's argument structure: The subject of a verb is often the semantic agent, and the direct object of a verb is often the semantic patient. Therefore, once children know something about how subjects and objects are marked in their language's syntax, they can recruit that information to figure out which thematic roles the participants are filling. Gleitman (1990) describes the syntax in this type of scenario as serving the role of a "mental zoom lens" that directs the learner's attention to the relevant portion of the world, and the intended construal of the event.

The ability to make use of syntax to interpret verbs appearing in event descriptions has been demonstrated in both preschool-aged children (Fisher, 1994, 1996; Nappa et al., 2009) and infants as young as 20 months (Brandone et al., 2006; Naigles, 1990; Perkins et al., 2024). In Naigles (1990) for instance, 25-month-olds were shown videos in which a novel verb was paired with a scene containing two characters. The characters engaged in both a causal action (a duck pushing a bunny) and a non-causal action (the duck and the bunny each moving their arms in circles). Infants heard a novel verb used in either a transitive syntactic frame ("The duck is gorping the bunny!") or an intransitive frame ("The duck and the bunny are gorping!"). Infants were then shown separate videos of the causal and non-causal action and asked to "find gorping!" Those who had heard *gorping* appear in a transitive frame preferred to look at the causal action, and those who had heard it in an intransitive frame preferred to look at the non-causal action. The syntax guided infants to pick out different components of the scene as being described by the novel verb.

Further studies demonstrate that young infants are capable of attending to a novel verb's argument structure even if the verb does not directly co-occur with a physical action, but is instead used in a certain syntactic frame several times prior to labeling an event (Arunachalam & Waxman, 2010; Fisher et al., 2010; Yuan et al., 2012; Yuan & Fisher, 2009). By tracking the syntax of the verb, infants come to expect that the verb will be used to describe certain types of events—e.g., that a transitive verb will describe causal events. Then, these expectations guide them in their interpretation of the event upon seeing an instance of it in the physical world.

While we have described this type of syntactic bootstrapping as involving a correspondence between argument structure and thematic roles, an alternative hypothesis has also been pursued: that infants simply count the number of arguments a verb has and expect it to match the the number of participants in an event (Fisher, 1996; Fisher et al., 2010; Lidz et al., 2003; Naigles, 1990). This procedure may seem more straightforward, but it does rely on the assumption that the number of conceptual participants in an event is clear and will be transparently reflected in the argument structure. However, exceptions to this type of one-to-one matching abound: For instance, "stealing" seems to have three participants conceptually (the agent doing the stealing, the patient being stolen from, and the thing stolen) but often appears in language with just two arguments (e.g., *She stole the box*). Furthermore, there is evidence suggesting that infants' expectations about argument structure are based on thematic roles specifically rather than the surface number of event participants (Gertner et al., 2006; Lidz et al., 2017; Perkins et al., 2024; see

Lidz (2022) for a detailed review). These findings support the conclusion that infants are able to recruit information about thematic roles from the argument structure of event descriptions. They can use that information, in combination with features of the extralinguistic context, to infer verb meanings.

## Attitude Verbs

A second class of words that pose a potentially significant learning problem for children is propositional attitude verbs—that is, verbs such as *want* and *know*, which refer to mental states and can express attitudes toward propositions (e.g., *She knows* [*he will be in class today*]; *He wants* [*to come to the party*]). For attitude verbs, the physical world is even less likely to be informative about their meanings. Mental states are not directly observable; we must infer what people believe and desire based on their behavior. Furthermore, though frequent, attitude verbs are often backgrounded in naturalistic conversation. In sentences like *I think she's on her way*, the attitude verb *think* is typically used to make an indirect assertion and is not itself salient. Because of these factors, the adult participants in the Gillette et al. (1999) Human Simulation Paradigm almost never correctly guessed instances of attitude verbs from the extralinguistic context alone. It is not surprising, then, that children also tend to acquire attitude verbs somewhat late, around 3–5 years (Harrigan et al., 2019; Perner et al., 2003; Shatz et al., 1983). While this has at times been suggested to be due to conceptual difficulties involved in understanding mental states (immature Theory of Mind: Astington & Gopnik, 1991; de Villiers, 2021), recent evidence indicates that children as young as 7 months old are capable of representing others' beliefs, even false ones (Kovács et al., 2010; Onishi & Baillargeon, 2005; Southgate & Vernetti, 2014). The difficulty with attitude verbs, then, is likely primarily with identifying them in the linguistic input and mapping the words to their meanings.

Fortunately, attitude verbs' syntactic distributions have the potential to help children with this task, as they contain a rich quantity of information about attitude verb meanings (Gleitman et al., 2005; White et al., 2018). Across languages, attitude verbs can embed clausal complements, as in *I think* [*she's on her way*]—a syntactic reflex of the fact that these verbs express an attitude toward a proposition. Children could therefore have a principled expectation that verbs which take clausal complements are attitude verbs. In line with this prediction, preschool children and adults who are exposed to a novel verb with a clausal complement, such as *Matt gorps that his grandmother is under the covers,* are able to infer that *gorp* refers to a mental state (Papafragou et al., 2007). This provides evidence that children may identify attitude verbs in the input by paying attention to which verbs embed clausal complements.

The syntax of attitude verbs also contains finer-grained cues to their meanings. Cross-linguistically, attitude verbs tend to cluster into two subclasses that differ in their syntactic and semantic properties: desire verbs, such as *want* and *need,* and belief verbs, such as *think* and *know*. However, the particular syntactic cues associated with each subclass vary somewhat across languages. In English, desire verbs typically take nonfinite complements (e.g., *I want* [*to go to school*]), while belief verbs typically take finite complements (e.g., *I think* [*she's at school*]). In Romance languages, there is a difference in mood; desire verb complements are often in subjunctive mood and belief verb complements are often in indicative mood. The unifying factor is that belief verb complements tend to resemble declarative main clauses (e.g., *She's at school*), whichever ways they are syntactically marked in a given language. Why would this be? Hacquard and Lidz (2019, 2022) propose that the correlation is based on a link between clause types and speech acts. Declarative clauses are canonically associated with making assertions, and similarly, belief verbs lend themselves to making indirect assertions—the point of saying a sentence like *I think she's at school* is often to assert the complement (*she's at school*). Under a *pragmatic syntactic bootstrapping* account, the link to speech acts (assertions) provides a principled explanation for why belief verb complements tend to resemble declarative main clauses, syntactically. Children could take advantage of this syntax-semantics correspondence by tracking which attitude verbs typically take complements with declarative main clause syntax, and hypothesizing that these are the belief verbs.

Experiments with preschoolers indicate that English-speaking children are in fact sensitive to the finiteness of the complement in their interpretations of an attitude verb (either with a novel verb like *gorp*: Lidz, 2017; or the relatively unfamiliar *hope*: Harrigan et al., 2019). In addition, computational work has demonstrated that a learner who used this type of strategy would successfully acquire belief and desire subclasses in both English (White et al., 2018b) and Mandarin (Huang et al., 2022). These findings provide evidence both that children attend to the relevant syntactic cues and that the syntactic cues are a reliable correlate of attitude verb subclass.

Here we see the syntax acting as a foothold that helps learners break into the right semantic field for the word. When faced with an extreme lack of information from the extralinguistic context, children can lean more heavily on the overall syntactic distribution to make the initial distinction between belief verbs and desire verbs. Other sources of information can then be recruited to learn the differences between verbs within the same subclass (e.g., for a pragmatic syntactic bootstrapping account of how children learn the difference between *think* and *know*, see Dudley, 2017).

## Bootstrapping Beyond Verbs

We have so far followed the literature in focusing primarily on verbs, but it is important to note that syntactic bootstrapping is a viable learning strategy for any type of word that exhibits principled syntax-semantics links in its distribution. For instance, Waxman and Booth (2001) found that 14-month-old infants were able to interpret novel adjectives (*This is a blickish one*) as referring to properties of objects, and novel nouns (*This is a blick*) as referring to object kinds. Evidence has also been found of children's

sensitivity to syntax in learning a novel preposition (Fisher et al., 2006) and a novel superlative determiner (*gleebest of the cows*) or adjective (*the gleebest cows*) (Wellwood et al., 2016).

## Conclusion

The goal of syntactic bootstrapping is to home in on word meanings; but we must note that in order to make use of their language's syntax at all, children will need to first acquire sufficient knowledge of it. To accomplish this feat, it has been hypothesized that children draw on early lexical-semantic (Fisher et al., 2020; Gleitman & Trueswell, 2020; Pinker, 1996) and/or prosodic (Christophe et al., 2008) knowledge. Hence the name syntactic *bootstrapping*: The acquisition of syntax and the acquisition of semantics do not happen sequentially or independently of one another. Rather, different types of cues, including some semantic information, initially support the acquisition of syntax, which in turn plays a key role in the acquisition of meaning.

We have also seen that, although the core of syntactic bootstrapping lies in systematic links between syntax and semantics, this process will crucially interact with other sources of information. Given an event description, the syntax and the extralinguistic context can jointly help a learner determine a perspective on an event. For propositional attitude verbs, children's expectations about the pragmatics of speech acts allow them to make the connection between belief verbs and complements with declarative main clause syntax. Wherever children would be justified in holding principled expectations about the correspondences between structure and meaning, we can hypothesize—and experimentally test—that syntactic bootstrapping plays a role in the acquisition of word meanings.

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