

One-for-One and Two-for-Two: Anticipating Parallel Structure between Events and Language

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1. Introduction

According to syntactic bootstrapping theory, children operate on the implicit assumption that there is a structural correspondence between events and language (Gleitman, 1990; Landau & Gleitman, 1985). This parallel structure implies that, by and large, there is a one-to-one relation between participants in an event and noun phrases in a clause. For example, transitive verbs, such as *push*, *kick*, or *eat*, have two noun phrase arguments and describe events with two participants (e.g., *Mary* kicked the *ball*); whereas intransitive verbs, such as *run*, *swim*, or *sleep*, have only one noun phrase argument and denote events with one participant (e.g., *Tom* is sleeping). Research suggests that children glean information about the meanings of verbs by attending to their accompanying syntactic frames (e.g., Fisher, 1996; Fisher, Hall, Rakowitz, & Gleitman, 1994; Hirsh-Pasek, Golinkoff, & Naigles, 1996; Naigles, 1990; Naigles, 1996). For example, children can exploit syntactic cues such as the number and arrangement of arguments in a sentence to zero in on verb meaning (Gleitman, 1990; Landau & Gleitman, 1985). But does this process work in reverse? This paper explores the question of whether toddlers

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can predict the syntactic frame for a novel verb on the basis of the structure of the event it labels.

1.1. Syntactic Bootstrapping

On syntactic bootstrapping, syntax provides a kind of mental “zoom lens” for interpreting a scene, constraining the possible verb meanings available from situational information. A vast body of literature suggests that children as young as 22 months of age use syntactic information to learn about verb meaning (e.g., Fisher, 1996; Fisher et al., 1994; Gleitman, 1990; Hirsh-Pasek et al., 1996; Naigles, 1990; Naigles, 1996). For example, using the intermodal preferential looking paradigm (IPLP) (Golinkoff, Hirsh-Pasek, Cauley, & Gordon, 1987), Naigles (1990) demonstrated that by 24 months of age, children use information from the number of noun phrases in an utterance to choose between plausible interpretations of a novel verb that differ on the basis of argument number. Naigles’ experimental design was as follows: During training children saw a single screen displaying a complex event involving two participants, a rabbit and a duck. The rabbit repeatedly pushed the duck down into a squatting position with one hand, while both the rabbit and the duck simultaneously made big circles in the air with their arms. During this event children heard either a transitive sentence (“The rabbit is *gorping* the duck”) or an intransitive sentence (“The rabbit and the duck are *gorping*”). In test, children saw the event split apart onto two separate screens. On one screen, the rabbit pushed the duck down without the arm circling action. On the other screen, the rabbit and the duck circled their arms without the squatting action. While both events were on the screen, children heard, “Where’s *gorping* now? Find *gorping*!”

Naigles’ (1990) results suggest that children used the syntax of the sentence in the training event to guide their interpretation of the meaning of the verb *gorping*. Those who heard the transitive sentence (“The rabbit is *gorping* the duck”) interpreted *gorp* as referring to the causative event (‘force to squat’), and those who heard the intransitive sentence (“The rabbit and the duck are *gorping*”) instead understood *gorp* to mean the noncausative event (‘circling one’s arms’). These results suggest that English-learning children use a one-to-one mapping principle as a guide to their interpretations of novel verbs (see also Fisher, 1996; Fisher et al., 1994; Hirsh-Pasek et al., 1996; Naigles, 1996).

This phenomenon also extends beyond the English language, occurring even in Kannada, an Indian language with very different linguistic properties. Like English, Kannada also uses two noun phrases to express events in which one participant causes another to do something. However, because Kannada (unlike English) commonly allows argument dropping, the most reliable cue for causation in Kannada is a causative verbal affix. Lidz, Gleitman, and Gleitman (2003) demonstrated that, whereas adult speakers of Kannada relied

on causative morphology over argument number in interpreting novel sentences, 3-year-olds ignored the more reliable morphological cue and instead depended on the less reliable cue of noun-phrase number. Overall these results suggest that, for beginning language learners, the number of arguments assigned to a verb is a particularly robust cue that drives inferences about verb meaning.

1.2. Semantic Bootstrapping

In addition to the principle of syntactic bootstrapping, is the principle of semantic bootstrapping, as proposed by Grimshaw (1981) and elaborated by Pinker (1982; 1984; 1987). Semantic bootstrapping is essentially syntactic bootstrapping in reverse: Whereas syntactic bootstrapping claims that children use syntax to predict semantics, semantic bootstrapping claims that children use semantics to predict syntax. In other words, children use a non-syntactic procedure to isolate the meanings of words and then use this semantic information to determine the syntactic properties of those words, such as form class and, in the case of verbs, subcategorization frames. According to the semantic bootstrapping hypothesis, children extract verb meaning from cross-situational observation of real-world events and then, based on (possibly innate) knowledge of syntactic/semantic linking rules, they infer the subcategorization privileges of the novel verb¹.

It is important to note that although syntactic and semantic bootstrapping are distinct and have often been treated as competing hypotheses, they are *not* mutually exclusive. More likely they work together and complement each other during the process of verb learning.

As compared to syntactic bootstrapping, the principle of semantic bootstrapping has received considerably less empirical attention (but see Gropen, Pinker, Hollander, & Goldberg, 1991). Support for semantic bootstrapping could conceivably require at least two different kinds of evidence: (1) nonlinguistic evidence revealing that young children's event representations are organized to provide a framework for interpreting argument structure and (2) linguistic evidence demonstrating that children can infer syntax from semantic event representations.

Evidence of the first kind comes from the work of Gordon (2003) and Scherf (2005). For example, in a between-subjects design, Gordon (2003), habituated infants to one of two nonlinguistic events involving three participants—a boy, a girl, and a toy. In the GIVE event, all three objects were essential participants in the action (i.e., the *girl* gives the *toy* to the *boy*). In the HUG event, only two of the objects were essential participants (i.e., the *girl*

1. The current paper will examine only this small aspect of the semantic bootstrapping hypothesis. For a broader, more in depth discussion, see Pinker (1982; 1984; 1987).

hugs the *boy* while holding the toy). Following habituation, infants were shown both the old and a new event. In the new event, the toy was removed from the scene. Thus, in the GIVE event, the girl makes the motion of giving to the boy despite the fact that no toy is present; in the HUG event, the girl hugs the boy without holding the toy. Visual fixation data revealed that 10-month-olds discriminated between the new and old test events only in the GIVE condition. Infants did *not* discriminate between HUG with an object and HUG without an object. Gordon argued that, together with a series of elaborate control conditions and eye-tracking data, these results suggest that by 10 months, infants can distinguish between relevant and irrelevant elements of an event's structure. Thus, long before they are able to verbally describe them, infants can form representations that encode the number of essential participants in an event. These data support the possibility that young children's event representations are organized to provide a framework for interpreting argument structure.

Evidence of the second kind for semantic bootstrapping (inferring syntax from semantics) comes from experimental studies using production tasks with much older children. Gropen et al. (1991), for example, taught 3-, 5-, and 7-year olds a novel verb in a gerund form ("This is *keating/mooping*") and tested them on their willingness to use that verb in various grammatical constructions. In this task, children were required to infer the syntax of the novel verb on the basis of the event it described. For example, one novel verb (*keating*) involved moving a cotton ball in a nondescript way to a piece of felt, causing the felt to change color. Gropen et al. predicted that if children understood the meaning of this event and the universal linking rule of object affectedness, they would produce sentences such as "You're *keating* the felt (with the cotton ball)". In contrast, another novel verb (*mooping*) involved moving the cotton ball to the felt in a zig-zagging manner without any resulting change to the felt. Gropen et al. predicted that based on their comprehension of the meaning of this event and the universal linking rule of object affectedness, children would alternatively describe this situation with sentences such as "You're *mooping* the cotton ball (onto the felt)". These predictions were confirmed: in each age group there was a significant difference in the pattern of responses depending on the nature and meaning of the action. Thus, results suggest that at least by 3- to 7-years of age, children are able to infer the syntax of a verb from the meaning of an event.

1.3. Present Studies

Although evidence exists for syntactic bootstrapping ability in children as young as 22 months, it is as yet an open question whether children younger than 3 years are similarly capable of semantic bootstrapping. The present studies explored whether toddlers are able to bootstrap from semantics to syntax. If the theory of semantic bootstrapping is correct, toddlers should infer

the subcategorization frame of a novel verb based on their understanding of the event that it labels. In other words, toddlers should expect that a verb describing a one-participant event will be intransitive, whereas a verb describing a two-participant event will likely be transitive.

We tested this prediction using a violation of expectations design. To trigger the process of semantic bootstrapping, we introduced toddlers to a bare, novel verb in the presence of a simple event. In Experiment 1, the event involved one participant; in Experiment 2, the event involved two participants. After toddlers habituated, we showed them the same event now accompanied by both intransitive and transitive sentence frames. Looking times during the test phase were used as a measure of whether or not the test events violated toddlers' expectations.

We predicted that if toddlers can infer the subcategorization privileges of a verb based on the structure of the event it describes, they should expect the number of syntactic arguments in the language they hear to *match* the number of participants in the event they see. Therefore, in the present research they should be surprised to hear a verb describing a one-participant event used in a transitive frame.

2. Experiment 1

In Experiment 1, toddlers were habituated to an event involving a single participant accompanied by a novel verb. If toddlers can bootstrap from semantics to syntax they should expect the novel verb to be intransitive. Thus, in a violation of expectations design, toddlers should be surprised to hear the novel verb for a single participant event used in a transitive frame. In other words, toddlers should look longer when they hear the novel verb in a transitive frame than when they hear it in an intransitive frame.

2.1. Methods

2.1.1. Participants

Participants were 14 full-term, monolingual, English-learning toddlers (6 male) between the ages of 16 and 17 months (mean = 16.95, SD = .63). Data from an additional 16 toddlers were excluded for the following reasons: parental or sibling interference (4), technical difficulty (1), fussiness (1), experimenter error (2), and reset test trials² (8).

2.1.2. Stimuli and Procedure

2. The minimum look time required for each test trial was 2 seconds. First looks lasting less than 2 seconds were not counted and the individual test trial was repeated. Data were excluded from toddlers for whom test trials were reset.

Participants were habituated to a single event in which a seated girl repeatedly moved her right arm up and down. Her right hand was held in a fist while her left hand rested on her lap. Behind her left shoulder, two brightly colored balloons were affixed to the wall. Note: Although the balloons were present in the scene, they did not participate in the event. Accompanying this event, toddlers heard a novel verb in a bare frame (“What is she doing? *Tooping?*”). A trial ended either when the participant looked away from the stimulus for two consecutive seconds, or when the trial had lasted 30 seconds, whichever came first. Toddlers were said to have habituated when their visual fixation during the last three trials dropped to 50% of that during the first three trials. Once habituated, each participant was presented with three test trials (control, intransitive, and transitive) in counterbalanced order. The only thing that varied between the habituation and test trials was the audio accompanying the event; in all three test trials, toddlers saw the same event they had seen during habituation. The control trial audio was identical to that in habituation. Toddlers heard, “What is she doing? *Tooping!*” In the intransitive test trial, toddlers heard the novel verb used in a single argument frame (“She’s *tooping!*”). In the transitive trial, toddlers heard the novel verb used in a dual argument frame (“She’s *tooping* them!”). Visual fixation during the test phase was used as a measure of whether or not the test events violated toddlers’ expectations.

2.2. Results

A 3×2 mixed model ANOVA with the dependent variable of visual fixation time, the within-subjects factor of trial type (control, intransitive, transitive), and the between subjects factor of gender revealed a significant main effect of trial type ($F(2, 24) = 4.05, p = .031$). Neither the main effect of gender ($F(1, 12) = .098, p = .760$) nor the trial type \times gender interaction ($F(2, 24) = .507, p = .609$) was significant. Planned contrasts revealed a significant difference between the intransitive and transitive test trials ($F(1, 12) = 10.729, p = .007$; see Figure 1).

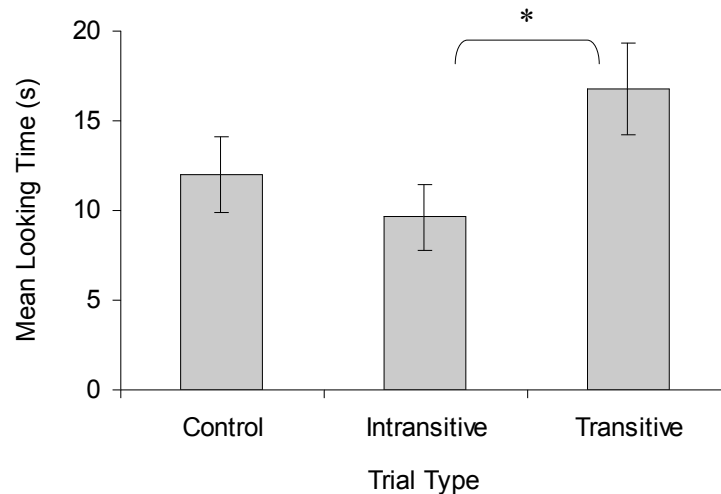


Figure 1. Experiment 1 (Single-participant event): Mean looking time by test trial type

2.3. Discussion

As demonstrated by their increase in looking, results suggest that toddlers were surprised to hear the novel verb *tooping* used in a dual-argument frame. Toddlers looked significantly longer when they heard “She’s tooping them” than when they heard “She’s tooping.” These results suggest that toddlers indeed operate under the implicit assumption that the number of arguments in a sentence cannot exceed the number of participants in an event. These results cannot occur solely on the basis of counting the objects visible in the scene since another set of objects—the balloons—was present. Thus, these data provide preliminary evidence for the semantic bootstrapping hypothesis. Results suggest that toddlers may be able to deduce the subcategorization frame of a novel intransitive verb on the basis of the structure of the event it describes.

However, there are two alternative reasons why toddlers may have looked longer when they heard the transitive frame. First, toddlers may look longer to the transitive frame simply because the sentence is longer. “She’s tooping them” has more words than “She’s tooping.” Thus, it may take more time to process the transitive than the intransitive frame, resulting in longer looking times. Furthermore, the transitive sentence frame is the most perceptually distinct. Whereas both the control and intransitive sentences end with the word “tooping,” the transitive sentence ends with the word “them.” This distinction could also potentially highlight the transitive sentence, resulting in longer looking times.

The purpose of Experiment 2 was to rule out these low level possibilities as well as to consider toddlers' expectations for a verb describing a two-participant event.

3. Experiment 2

In Experiment 2, toddlers were habituated to an event involving two participants. If toddlers can bootstrap from semantics to syntax they should now expect the novel verb to be *transitive*. Thus, if toddlers use the number of participants in an event to infer the subcategorization frame of a novel verb, they should not be surprised to hear it used in a transitive frame.

What about the intransitive frame? Would toddlers be surprised to hear a two-participant event described with a single noun phrase? We predicted that they would not. As adults, we have no problem comprehending truncated transitives. Consider, for example, the transitive verb *push*. We can say "Johnny got in trouble for pushing" just as easily as we can say "Johnny got in trouble for pushing *Mary*." We confirmed this intuition with a small adult pilot study that simulated our infant design (Pulverman, Addy, Molfese, & Golinkoff, 2003). Results suggested that adults do not find it grammatically *unacceptable* to describe a two-participant event with an intransitive sentence. We predicted the same would be the case for toddlers. If toddlers can infer the subcategorization privileges of a verb describing a two-participant event, neither the intransitive nor the transitive sentences should violate their expectations. Toddlers should not be particularly surprised by any of the test trials.

3.1. Method

3.1.1. Participants

Participants were 14 full-term, monolingual, English-learning toddlers (9 male) between the ages of 16 and 17 months (mean = 17.05, SD= .69). Data from an additional 20 toddlers were excluded for the following reasons: parental or sibling interference (3), failure to reach the habituation criterion within 15 trials (3), technical difficulty (1), fussiness (4), and reset test trials² (9).

3.1.2. Stimuli and Procedure

Stimuli and procedures were identical to those in Experiment 1 with one important exception: Toddlers were habituated to an event involving two participants—both the girl and the balloons. Participants watched an event in which the seated girl repeatedly moved her right arm up and down; however, now the brightly colored balloons were held in her right fist. Thus, in the two-participant event, the girl moved the balloons up and down repeatedly.

Accompanying this event, toddlers heard “What is she doing? *Tooping!*” just as in Experiment 1. Once habituated, each participant was presented with three test trials (control, intransitive, and transitive) in counterbalanced order. The test trials were identical to those in Experiment 1. The only difference was in the video: the accompanying event now involved two participants.

3.2. Results

A 3×2 mixed model ANOVA with the dependent variable of visual fixation time, the within-subjects factor of trial type (control, intransitive, transitive), and the between subjects factor of gender revealed no significant effects. Neither the main effect of trial type ($F(2, 24) = .798, p = .462$), nor the main effect of gender ($F(1, 12) = .001, p = .970$) was significant. The trial type \times gender interaction ($F(2, 24) = 1.664, p = .210$) also failed to reach significance. Planned contrasts revealed no significant difference between the intransitive and transitive test trials ($F(1, 12) = .668, p = .430$; see Figure 2).

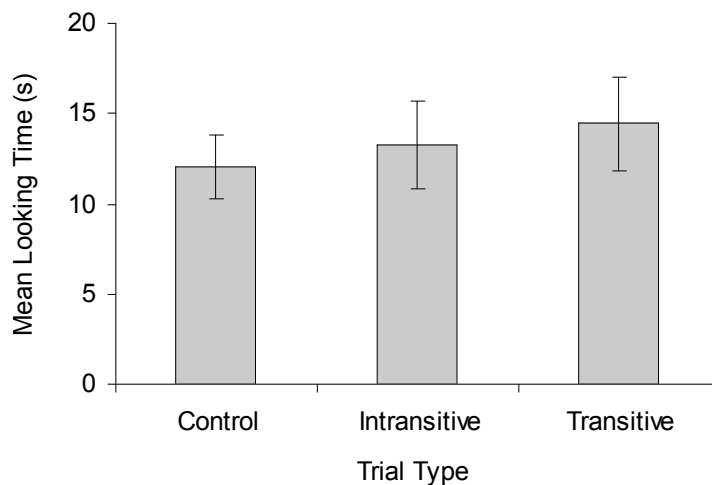


Figure 2. Experiment 2 (Two-participant event): Mean looking time by test trial type

3.3. Discussion

Visual fixation data from Experiment 2 showed no significant differences in toddlers’ looking during the control, intransitive, or transitive test trials. Toddlers were not particularly surprised to hear “She’s tooping” or “She’s tooping them.” This finding suggests that the length or perceptual distinctiveness of the sentence alone is not responsible for the effect in Experiment 1.

There are two possible explanations for the lack of significant findings in Experiment 2. The first is that toddlers may interpret the novel verb as transitive and accept both transitive and intransitive (or in this case truncated transitive) frames to describe it. The second possibility is that, given the novel nature of the event and the ambiguity of the word-to-world mapping, toddlers may have been unsure about whether the novel verb was transitive or intransitive. If this were the case, neither the intransitive nor the transitive sentence should violate their expectations because toddlers have not formed clear expectations about the verb's subcategorization frame. We cannot choose between these explanations based on the current data. Nevertheless, Experiment 2 demonstrates that toddlers are not just looking longer during the transitive test trial in Experiment 1 simply because it has more words or is more perceptually distinct. Results from Experiment 2 secure the finding from Experiment 1 that toddlers are indeed capable of using semantic bootstrapping.

4. General Discussion

The combined results of Experiments 1 and 2 suggest that, by the age of 17 months, toddlers comprehend the parallel structure of language and events. This finding is not entirely new; similar evidence can be found in the syntactic bootstrapping literature (e.g., Fisher, 1996; Fisher et al., 1994; Landau & Gleitman, 1985; Naigles, 1990). However, the current experiments add that, based on their knowledge of this parallel structure, toddlers may also be able to bootstrap from semantics to syntax, inferring the subcategorization frame of a novel verb on the basis of the structure of the event that verb describes. Thus, results suggest that by this early age, toddlers understand that verbs labeling one-participant events must be intransitive, whereas verbs labeling two-participant events can be either intransitive or transitive.

What is the role of this semantic bootstrapping ability in the process of language learning? How helpful is the ability to bootstrap from semantics to syntax? And, where does it fit with syntactic bootstrapping? As Gleitman, Snedeker and colleagues have demonstrated in the Human Simulation Project (Gillette, Gleitman, Gleitman, & Lederer, 1999; Gleitman, Cassidy, Nappa, Papafragou, & Trueswell, 2004; Snedeker, 2000; Snedeker & Gleitman, 2004), the process of word-to-world mapping is often unreliable, especially in the case of words whose event counterparts are less obvious in a scene. Extralinguistic contexts alone do not generally contain enough information to determine verb meaning. Children often need syntactic cues to narrow the possible meanings available from situational information. Syntactic bootstrapping thus enables children to learn the meanings of verbs when observation fails. However, the verb learning problem includes more than just learning verb *meaning*. Knowing the subcategorization privileges for each verb is also part of what it means to know one's language. Results of the

current experiments suggest that these essential syntactic properties of verbs may be bootstrapped from semantics.

Thus, syntactic and semantic bootstrapping appear to be complementary processes. Whereas syntactic bootstrapping enables children to learn the meaning of less obvious words on the basis of syntactic cues, semantic bootstrapping may enable children to learn the syntactic properties of referentially transparent verbs. In this way, knowledge of syntax supports the learning of semantics and knowledge of semantics supports the learning of syntax.

5. Conclusion

Results of the current experiments provide some of the first evidence suggesting that, at least in certain circumstances, toddlers may be capable of semantic bootstrapping. By 17 months of age, often before they are even combining words, toddlers expect there to be a correspondence between language and events. Furthermore, when the situation allows, toddlers may be able to use this information to form hypotheses about the subcategorization privileges of novel verbs.

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