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# REPORT

# Structural limits on verb mapping: the role of abstract structure in 2.5-year-olds' interpretations of novel verbs

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### Abstract

*Two experiments showed that 2.5-year-olds, as well as older children, interpret new verbs in accord with their number of arguments. When interpreting new verbs describing the same motion events, children who heard transitive sentences were more likely than were children who heard intransitive sentences to assume that the verb referred to the actions of the causal agent. The sentences were designed so that only the number of noun-phrase arguments differed across conditions (e.g.* She's pilking her over there *versus* She's pilking over there*). These experiments isolate number of noun-phrase arguments (or number of nouns) as an early constraint on sentence interpretation and verb learning, and provide strong evidence that children as young as 2.5 years of age attend to a sentence's overall structure in interpreting it.*

In adult language processing, it is taken for granted that the syntactic structure of an utterance affects its interpretation. In 'John hits Bill', for example, it is the positioning of John and Bill in the sentence that tells us which is the guilty party and which the victim. As adults, we routinely use links between syntax and meaning both to generate utterances and to understand them. The central claim of the syntactic bootstrapping theory is that precursors of these links between structure and meaning play a role in the initial development of the child's system for interpreting sentences (e.g. Fisher, Gleitman & Gleitman, 1991; Gleitman, 1990; Landau & Gleitman, 1985). This claim is supported by many experiments showing that children between about 2 and 5 years of age take novel verbs in different sentence structures to have different meanings (Fisher, 1996; Fisher, Hall, Rakowitz & Gleitman, 1994; Landau & Stecker, 1990; Naigles, 1990, 1996; Naigles, Gleitman & Gleitman, 1993; Naigles & Kako, 1993).

For example, Naigles (1990) presented 25-month-olds with a videotape showing two simultaneous events (e.g. a duck bends a bunny over, while both duck and bunny make arm circles). This combination was paired with a nonsense verb in either a transitive (e.g. 'The duck is blicking the bunny!') or an intransitive ('The duck and the bunny are blicking!') sentence. The two events (e.g. bending and arm-circling) were then shown separately on two video screens, and the child was told to 'Find blicking!' The children who had heard the transitive verb looked longer at the causal scene (e.g. bending), while the children who had heard the intransitive verb looked longer at the noncausal scene (e.g. arm-circling). These very young children thus used syntax to guide their interpretation of a sentence, and to learn a new verb.

How does this learning process work? That is, what aspects of sentence structure do children identify relatively early in the process of acquiring a language, and how do they use this knowledge to constrain utterance interpretation?

Recent experiments have begun to isolate a particular structural cue that could influence early sentence interpretation (Fisher, 1996). Three- and 5-year-olds and adults learned novel verbs for unfamiliar agent-patient events. The novel verbs were either transitive (e.g. 'He's pilking him fast') or intransitive (e.g. 'He's pilking fast'). The key feature of these experiments was that the identity of the subject and object of the sentences was hidden by using ambiguous pronouns, yielding sentences that differed only in their number of noun phrase arguments. The children's and adults' interpretations of the novel verbs were assessed by asking them to point to the participant whose role the verb described (e.g. 'Which one pilked the other one fast?' vs 'Which one pilked fast?').

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Both the children and the adults were more likely to choose causal agents as the subjects of transitive than intransitive sentences.

Since the only difference between the two critical sentence contexts was in their number of noun phrase arguments, this result is evidence that the entire structure of the sentence, the configuration of arguments itself, was meaningful to the children. In previous studies of the role of syntax in verb interpretation, the linguistic contexts of novel verbs have always specified the identity of the verbs' arguments (as in 'The duck is blicking the bunny', describing a scene in which these characters participated; Fisher *et al*., 1994; Naigles, 1990, 1996; Naigles & Kako, 1993). These sentences therefore provide many potential influences on sentence interpretation. The ambiguous pronoun task described above, in contrast, forces children to rely on the sentence's configuration of arguments to guide interpretation. Positive results thus indicate that the structure of the sentence *per se* caused the children to adopt different perspectives on the same event.

The present experiments asked whether 2-year-olds show the same sensitivity as older children and adults to overall sentence structure in the interpretation of novel verbs. Different views of the nature of early grammatical knowledge offer different predictions on this question.

The syntactic bootstrapping theory holds that children use information about sentence structure to guide sentence comprehension from an early point in acquisition. Fisher *et al*. (1994; Fisher, 1996, 2000a) proposed that children might arrive at a structure-sensitive interpretation of a sentence by structurally aligning a representation of a sentence with a structured conceptual representation of a relevant scene. Thus a child might infer that a sentence with two arguments must describe some real-world relation between the two referents, while a sentence with only one argument might describe an act or property of a single participant.

This simple structural alignment could take place as soon as the child can identify some nouns and represent them as parts of a larger utterance: that is, a child might assume that a sentence containing *two nouns* denotes a conceptual relation between the two referents, and that a sentence containing only one noun describes a one-place conceptual predicate. This simple counting-the-nouns process would lead to some interpretive errors – I will return to this issue in the Discussion – but would still provide some useful constraint on interpretation.

According to the syntactic bootstrapping view, gross structural properties of sentences would thus guide the selection of an appropriate conceptual representation, providing vital cues as to what aspect of a situation the sentence describes (Fisher, 1996; Fisher *et al*., 1994; Gillette, Gleitman, Gleitman & Lederer, 1999; Gleitman, 1990). This structure-mapping procedure requires that children represent sentence structures in an abstract format, and use this abstract structure in interpreting sentences. However, controversy has long raged over when and how young language learners begin to be influenced by abstract structural representations of utterances. Some researchers have recently argued that relatively abstract representations of sentence structures, and precursors to the adult links between syntax and semantics, play a minimal role in the early phases of language acquisition (e.g. Clark, 1996; Lieven, Pine & Baldwin, 1997; Pine, Lieven & Rowland, 1998; Tomasello, 1992). This position is based on observations that children are quite conservative in their early production of language. Children do eventually produce errors in which they combine verbs with unattested sentence structures (e.g. Bowerman, 1981, 1990; Choi, 1997; Pinker, 1989), but these are late errors, following a period during which children seem to combine verbs and sentence structures only in patterns that are present in the input (e.g. C.L. Baker, 1979). Tomasello and colleagues have documented the same phenomenon in children's elicited productions of newly learned verbs: if an experimenter models a new verb for children in a transitive sentence, 2-year-olds readily produce new transitive uses of the verb when encouraged to do so. If the experimenter models the new verb in an intransitive structure, 2-year-olds are far less likely to use the new verb in a transitive sentence (e.g. Brooks & Tomasello, 1999; Tomasello, 2000).

These findings appear to be in conflict with the requirements of early syntactic bootstrapping. Innovative combinations of verb and sentence structure make clear that a sentence structure has a separate reality in the child's growing linguistic system. If this recombination is a late development, not appearing until nearly 3 years of age for newly learned verbs, then how could children use sentence structure cues to narrow down their initial interpretations of sentences containing novel verbs? More generally, if errors that show productive links between syntax and semantics occur relatively late in development, then how could any sort of syntax-semantics links play a causal role in early acquisition (Bowerman, 1990)?

There are important reasons to suspect that this conflict is more apparent than real (Fisher, 1996; Fisher *et al*., 1991, 1994; Gleitman, 1990; Gillette *et al*., 1999). According to syntactic bootstrapping theory, abstract representations of sentence structure guide the early

interpretation of sentences. This argument concerns representations and processes for *interpreting attested utterances*, not for generating innovative departures from observed combinations of lexical items and sentence structures. To see why these processes might show very different patterns, we need to unpack the steps involved in each.

What might be required to predict that a known verb should be able to occur in an unattested sentence structure? Debate on this question has centered on two general views of the role of linking regularities in acquisition: in one view, the semantic bootstrapping theory, rules that link semantic structures with syntactic structures are innately specified as part of the human language acquisition faculty, and supplemented by learning about the lexical choices of a particular language (e.g. Grimshaw, 1981; Pinker, 1989). In the other view, regularities in the linking of semantic roles and grammatical functions are largely acquired (e.g. Bowerman, 1990). If the syntax-semantics linking rules are entirely learned, then innovation should clearly be late-appearing: children must first detect regularities relating the forms and meanings of sentences in their native language before they can produce sentences that reflect these regularities. Even on the innate linking-rule view, however, the innovative combination of verbs and sentence structures should be a late development. This conclusion follows from two considerations: first, in order to generate a recognizable attempt at a sentence structure based on links between meaning and syntax, children must already have figured out how grammatical functions (subject, object, oblique) are expressed in their particular languages. Thus, on an innate linking-role view, the greater part of syntax acquisition must be complete before productive innovation is possible. Second, regardless of the source of syntax-semantics links, the appearance of productive innovation requires that the child have already developed a language production mechanism with procedures for retrieving or building sentence structures based only on meaning, unaided by practiced links between particular lexical items and their structures. Experience with particular verbs in particular sentence structures has measurable effects on language production and comprehension even in adults (e.g. Pickering & Branigan, 1998; Garnsey, Pearlmutter, Myers & Lotocky, 1997; Trueswell & Kim, 1998), and children's overall conservatism makes it very clear that they are learning item-wise facts about which verbs and sentence structures go together. These findings suggest that it should be harder for anyone, child or adult, to produce a sentence with an unfamiliar verb-structure combination than with a familiar one.

None of these accomplishments are required for the child to use the structure-mapping interpretative procedure proposed by the syntactic bootstrapping theory: by hypothesis, in order to gain some initial constraint on interpretation from sentence structure, children need only identify some nouns in sentences, and be endowed with a simple bias to map each referential term in an utterance onto a potential referent in a conceptual representation. On this view, the initial influence of sentence structure on sentence interpretation does not depend on (a) detailed rules linking syntactic and semantic functions (whether acquired or innate), (b) the identification of true syntactic structures, with all the language-specific syntax learning that implies (Fisher, 1996, 2000a), or (c) a fully developed language production system.

Evidence that syntax affects young preschoolers' interpretation of new verbs has direct consequences for the interpretation of the data on conservative verb use in early production. Three- and 5-year-olds who see the same causal event but hear a new verb presented as transitive or intransitive tend to assign different interpretations to the novel verb. If even younger children do the same, then this provides an additional reason why early productions of a new verb would be strongly influenced by the syntactic context in which it was presented. If young children assign different meanings to new verbs depending on their syntactic contexts, then we should not expect children to readily extend new verbs to unattested syntactic contexts.

To summarize, children between 2 and 3 have been found not to stray far from the adult model in their productions with novel verbs. Such data have recently been taken as evidence that abstract representations of sentence structure play little role in early acquisition. I have argued, on the contrary, that the creative recombination of words and sentence structures in language production depends on several steps that would not be required for abstract representations of sentences to influence language comprehension. The structure-mapping mechanism for early syntactic bootstrapping sketched here strongly predicts that children well under 3 years of age will be influenced by skeletal aspects of sentence structure in the interpretations of novel verbs, despite their productive conservatism with new verbs. In particular, sentences differing only in their number of noun-phrase arguments should be interpreted differently by children in this younger age group, just as they are by 3- and 5-year-olds. The experiments reported here tested this prediction. The simple pronoun disambiguation task previously used with 3- and 5-year-olds (Fisher, 1996) was adapted for use with 2.5-year-olds;

3-year-olds and adults were included for comparison with prior findings.

## Experiment 1

### *Method*

#### Subjects

Twenty-four 2.5-year-olds (12 girls, 12 boys; mean age 29.7 months, range 27–32 months), 23 3-year-olds (12 girls, 11 boys; mean age 38.9 months, range 35–43 months), and 24 college-aged adults (12 female, 12 male) participated in a language comprehension task. All were native speakers of English. Six additional 2.5-year-olds and 10 additional 3-year-olds were tested but were excluded from the analysis due to unwillingness to respond to the experimenter's questions (6 2.5-year-olds and 9 3-year-olds) or parental coaching (1 3-year-old). Children received a book or small toy as a reward for their participation; adults received partial credit in an introductory psychology course. Children and adults were randomly assigned to either the Transitive or Intransitive condition and to one of two stimulus orders.

#### Stimuli

Four brief caused-motion events were videotaped. In each, one active participant (the agent) directly caused the motion of a passive participant (the patient; see Table 1 for event descriptions). The events varied in length between approximately 6 and 15 seconds; each began and ended with both participants at rest. Each event was enacted by two female participants, and each person participated in only one videotaped stimulus event. In two events the agent was on the left; in the other two she was on the right. The events were edited into two sequences, one the order shown in Table 1, and the other its reverse. Each videotaped event appeared 3 times in a row on the videotapes, separated by brief intervals of blank screen. Each event sequence was followed by a 5-second still frame showing the approximate midpoint of the motion.

**Table 1** *Stimulus events and sentences*

| Unfamiliar motion events | Stimulus sentences |
|---|---|
| Participant A pulls B backwards along a slippery surface by pulling on B's backpack. | She stipes (her) over there! |
| A rolls B toward her on a wheeled dolly, by pulling on a feather boa tied around B's feet. | She braffs (her) over there! |
| A wheels B forward and back in a red wagon. | She pilks (her) back and forth! |
| A rotates B on a swivel stool by pulling on the ends of a scarf around B's waist. | She gishes (her) around! |

The two sentence contexts for each item differed in the number of noun-phrase arguments specified. The Transitive sentences mentioned both participants, while the Intransitive sentences included only one. Since the participants were identified as 'she' and 'her', these sentence contexts provided only structural information about the verb, not direct clues as to the identity of the subject or object of the verb. The directional phrases (around, over there, and back and forth) were added to help identify the verbs as motion verbs, and were carefully chosen to apply to the motion of either character (as in Fisher, 1996). For example, in the first event shown in Table 1, both agent and patient moved 'over there' during the course of the event.

The nonsense verbs in their sentence contexts were recorded onto the soundtrack of the tapes. Each verb in its sentence context was first heard during the blank screen interval preceding the first repetition of the event, and repeated (in appropriate tenses) 9 times during and between the 3 repetitions of each event, according to a standard script. The script was recorded in an animated, child-directed style. This very repetitive soundtrack was designed, based on pilot work, to help the younger children clearly identify the sentence structure for the novel verbs.

#### Procedure

Each session began with a brief warm-up play period designed to accustom the child to interacting with the experimenter. The child was then brought into the testing room, and seated in front of a video monitor. The experimenter sat slightly behind the child, to make it impossible for the child to see the experimenter and the video screen at the same time. When a parent accompanied the child into the test room, he or she also sat behind the child's line of sight and was asked not to interact with the child during the procedure. The experimenter told the child to watch and listen carefully to the video, and then started the tape. After the third repetition of the first motion event, the experimenter paused the tape, leaving the still frame of the motion event visible on the screen, and said either 'Which one (verb)ed the other one . . . ? Point!' (Transitive condition) or 'Which one (verb)ed . . . Point!' (Intransitive condition). The test question provided the same syntactic information about each verb given in the prior familiarization sentences. The experimenters encouraged guessing, but

**Table 2** *Mean (se) proportion agent choices by age and sentence context, Experiment 1*

| Age group | Intransitive | Transitive | Mean |
|---|---|---|---|
| 30 months | 0.326 (0.110) | 0.625 (0.104) | 0.476 (0.080) |
| 40 months | 0.045 (0.045) | 0.667 (0.089) | 0.370 (0.083) |
| Adults | 0.313 (0.088) | 1.00 (0.000) | 0.656 (0.084) |
| Mean | 0.233 (0.054) | 0.764 (0.053) | |

never pointed to the screen themselves, and never asked the child to point again once the child had pointed on the screen. The experimenter always responded to the child's choice with 'good' and applause. The experimenter recorded the child's choice, and then invited the child to watch the next one. Children who did not make a choice on at least 3 of the 4 items were excluded from the analysis (see Subjects section); the 2.5- and 3-year-olds whose data were included made choices on 182 of the 188 total trials.

Adult subjects watched the same stimulus tapes and were asked the same questions. Before the procedure they were told that the materials were designed for young children, that we were gathering the intuitions of adult English speakers about the possible meanings of made-up words, and that there were no right or wrong answers.

### *Results*

As shown in Table 2, both the children and adults who heard Transitive sentences were more likely than were those who heard Intransitive sentences to point to the agent of each causal event. Across ages, listeners chose agents as the participant whose action the novel verb described for 76.4% of transitive verbs and 23.3% of intransitive verbs. The effect of a sentence's structure on its interpretation was seen for each age group and for each of the 4 event/verb pairs.

This pattern was tested in an ANOVA on the proportion[1] of agent choices, with age group (30 months, 40 months and adult) and sentence context (Transitive vs Intransitive) as between-subjects factors. There was a significant effect of sentence context ($F(1,65) = 62.86$, $p < 0.001$). Planned, one-tailed comparisons revealed significant differences between the Transitive and Intransitive conditions for each age group (2.5's: $t(22) = 1.99$, $p < 0.05$; 3's: $t(21) = 5.99$, $p < 0.001$; adults: $t(22) = 7.87$, $p < 0.001$). At each age, agent choices were significantly more likely in the Transitive than the Intransitive condition.

The ANOVA also revealed an effect of age group ($F(2,65) = 6.61$, $p < 0.01$) and a significant interaction of age and sentence context ($F(2,65) = 3.24$, $p < 0.05$). Posthoc tests (Bonferroni-adjusted) revealed that the adults chose agents in the Transitive condition significantly more often than did the 2.5-year-olds. Inspection of Table 2 suggests that the interaction of age and sentence context in the overall analysis stems from a simple tendency for the younger children to be less systematic in their responses in this task, as should be expected in any judgment task.

## Experiment 2

Because the results from the youngest age group are of such importance in evaluating the effect of abstract representations of sentence structure in acquisition, an additional 24 2.5-year-olds were recruited from the same source and tested in the same manner as in Experiment 1 (12 girls, 12 boys; mean age 30.1 months; range 28.3–32.2 months). Six additional children were tested but excluded from the analysis, due to unwillingness to respond (3), parental coaching (1), or choosing from only one side of the screen[2] (2). Children whose data were included in the analysis made choices in 93 of 96 opportunities. As in Experiment 1, the children who heard the Transitive soundtrack chose agents as the subjects of the novel verbs reliably more often than did the children who heard the Intransitive soundtrack (Transitive: 0.549, SE = 0.096; Intransitive: 0.285, SE = 0.077; $t(22) = 2.15$, $p < 0.05$).

### *Comparison of Experiments 1 and 2*

In a final set of analyses, the data obtained with the 2.5-year-olds in Experiments 1 and 2 were combined. The children ($n = 48$) were divided by a median split into younger (mean age 28.6 months; range 27.1–30.1) and older age groups (mean age 31.1 months; range 30.3–32.3). These groups turned out to be evenly divided across experiments (12 older and 12 younger children in each experiment) and genders (12 boys and 12 girls in each age split) and roughly evenly divided across conditions (Transitive: 14 younger and 10 older children; Intransitive: 10 younger and 14 older). An ANOVA on the

[1] All analyses of proportional data are conducted on arcsine-transformed proportions, with proportions of 0 replaced by $(1/(4n))$ and proportions of 1 replaced by $(1-1/(4n))$, where $n$ equals the number of observations on which each proportion is based, as suggested by Kirk (1982). Untransformed proportions are reported in text and tables; analyses on transformed and untransformed proportions yielded the same results in every case.

[2] This exclusion criterion was not used in Experiment 1, but was added in the replication to help reduce subject variation in the youngest group. Two 3-year-olds and 3 2.5-year-olds in Experiment 1 chose participants from one side of the screen in all 4 trials.

proportion of agent choices revealed only an effect of sentence context ($F$ (1,40) = 7.23, $p < 0.01$), with no effects of Experiment, Age group, or interactions involving these factors (all $F$s < 1). Planned, 1-tailed comparisons showed that (a) the younger children in the Transitive condition chose agents reliably more often (0.595, SE = 0.080) than did those in the Intransitive condition (0.367, SE = 0.097; $t$ (22) = 1.85, $p < 0.05$), and (b) the same was true of the older children (Transitive: 0.575, SE = 0.129; Intransitive: 0.262, SE = 0.090; $t$ (22) = 2.06, $p < 0.05$).

## Discussion

In two experiments, children as young as 28 months of age were influenced by abstract features of sentence structures in their interpretations of sentences containing a novel verb. Children who heard a transitive sentence while watching an event were more likely to assume that the verb described the actions of the causal agent than were children who heard an intransitive sentence. The sentences were designed so that only the number of noun-phrase arguments differed across conditions ('She's pilking her over there' vs 'She's pilking over there'). Thus we can conclude that the configuration of arguments in the sentences was meaningful to the children. Even children under 2.5 years old interpreted the subject referent to 'mean' different things – play different roles – in the same event, depending on the overall structure of the sentence. Simply put, sentence subjects are not preferentially the agents of causal events unless the verb has two noun-phrase arguments.

These results confirm the prediction made in the Introduction. Despite the well-documented fact that children under 3 years of age are quite unwilling to innovate in their own uses of newly learned verbs (e.g. Akhtar & Tomasello, 1997), children well under 3 are readily influenced by abstract properties of syntactic structures when *interpreting* sentences containing novel verbs. This apparent mismatch in the role of abstract structure in sentence production and comprehension during acquisition follows from the very different informational requirements of productive innovation and the interpretation of observed utterances. To reprise: even innately specified links between abstract meanings and abstract syntactic functions could not be used to generate innovative sentences until the child had (a) learned how those syntactic functions are expressed in a particular language (with its particular word order and morphology), and (b) developed a language production system that reflects these regularities robustly enough to generate a sentence structure without the support of a practiced verb-structure combination. Neither of these steps would be required for the structure-mapping mechanism for early syntactic bootstrapping proposed here and elsewhere (Fisher, 1996, 2000a).

The comprehension data reported here are consistent with prior findings on the role of abstract configural properties of sentences in novel verb comprehension (Fisher, 1996), and extend these findings to younger children. All of the experimental evidence for effects of sentence context on verb interpretation strongly implicate a role for abstract representations of sentence structure in young children's developing comprehension processes (e.g. Fisher *et al.*, 1994; Naigles, 1990, 1996; Naigles & Kako, 1993). These data support the view that the abstract representation of language input is an early-appearing and general property of learning mechanisms relevant to language acquisition. The current data isolate number of noun-phrase arguments as an early constraint on sentence interpretation and verb learning, and provide strong evidence for young children's sensitivity to a sentence's overall structure in sentence interpretation.

Crucially, the current data also suggest an additional reason for children to be conservative with verbs in early language production. Even 28-month-olds who are taught transitive versus intransitive verbs, applied to the same scene, will come to different conclusions about what those verbs were used to mean. These different semantic conclusions should affect the child's future use of the verb.

For example, suppose a child is taught an intransitive verb applied to a caused-motion event: an experimenter launches an Ernie toy using a slingshot and says 'Ernie pilked!' This child might conclude, as the 2.5-year-olds in our experiments did, that the new intransitive verb refers to the motion of the patient character in the event. We might gloss this as 'Ernie soared' or 'Ernie fell.' If later prompted to produce a transitive use of the same verb to describe the slingshot action (e.g. 'You pilked Ernie'), this child would be required not only to produce a novel combination of a verb and syntactic structure, but also to extend the meaning of the verb to suit the new sentence structure.

Such extensions are often not warranted. English does often use the same motion verb both transitively to describe an agent's action on an object (e.g. he *moved* it) and intransitively to describe the resulting motion of the object (e.g. it *moved*). But other motion verbs are only transitive (e.g. he *pushed* it) or only intransitive (e.g. it *fell*; see Levin, 1993, for an extensive list of examples). In these cases, different verbs describe the causal act and the resulting motion. Languages differ in how readily they permit a single verb to occur in multiple syntactic structures – and therefore with different senses – and in which pairs of verb meanings happen to be expressed

by the same verb (e.g. Bowerman, 1990; Pinker, 1989). Therefore the child cannot know *a priori* whether a particular new verb is like *move*, and can be used both transitively and intransitively, or like *push* or *fall*, which select only one of those two structures.

For a child to guess that a verb observed in one sentence structure can be extended to another requires not only abstract knowledge of the structure, but also a risky semantic conjecture – the conjecture that a verb's meaning can be altered to accommodate the new sentence structure. The current evidence tells us that children as young as 28 months old assign different interpretations to transitive and intransitive sentences containing new verbs. These different interpretations provide an additional reason why children might fail to extend the new verb to a new sentence structure – or at least an additional requirement to be met in doing so.

### *Early sentence comprehension and verb learning*

Two limitations of the present findings should be discussed: first, since the critical sentence context (transitive or intransitive) is presented in the test question, these data directly concern the interpretation of sentences containing novel verbs, but do not address the child's ability to remember the sentence context in which the new verb was presented, or to remember the interpretation of the verb. Considerable evidence suggests that children at this age and younger routinely accomplish both of these feats, however: observations that 2-year-olds use verbs conservatively (e.g. Olguin & Tomasello, 1993) make clear that very young children, like adults, retain information about which verbs have occurred in which sentence structures. In addition, Naigles found that children under 2.5 years of age show effects of syntactic structure on verb interpretation when the verb is presented in isolation at test (Naigles, 1990; Naigles & Kako, 1993).

Second, what can we say about how the children understood each sentence type? We can conclude with confidence that transitive and intransitive sentences are interpreted differently. The difference in interpretation between transitive and intransitive sentences was sensible: children in the transitive condition were more likely than children in the intransitive condition to choose an agent-subject interpretation. Other evidence also suggests that children under 3 years of age possess a reasonable understanding of the transitive sentence structure. Akhtar (1999) taught children made-up verbs for novel actions, presenting each verb either in normal English Subject-Verb-Object order (e.g. 'Ernie meeking the tree') or with an ungrammatical word order (e.g. 'Ernie the tree meeking' or 'Meeking Ernie the tree'). In an elicited production task, 2.67-year-olds were perfect in reproducing items with SVO order, but only half as accurate in reproducing the ungrammatical orders. These data suggest that the children already had some abstract knowledge of the English transitive sentence. In addition, Fisher (2000b) found that 26- and 21-month-olds used word order sensibly to interpret transitive sentences containing novel verbs. In a preferential looking task, two versions of the same causal action appeared simultaneously on two video screens. In one, a rabbit rotated a duck on a swivel stool. In the other, the duck did the same to the rabbit. At test, children heard one of two transitive sentences, differing only in word order ('The bunny is blicking the duck around' vs 'The duck is blicking the bunny around'). The test trial was preceded by a series of trials designed to familiarize the children with the two characters and test events, but to provide no information about the significance of word order. Both 26- and 21-month-olds looked longer at the screen on which the subject of their sentence was the agent of the causal action. Both of these sources of evidence provide some reason to think that children make early progress in understanding transitive sentences.

### *Assumptions of the structure-mapping view*

The data presented here implicate a role for abstract representations of sentence structure in early sentence interpretation. What is the nature of these abstract representations, and how do they influence early verb interpretation? The structure-mapping mechanism for early syntactic bootstrapping has a number of advantages as a target for ongoing inquiry: it follows naturally from a few widely shared assumptions about representations and learning mechanisms relevant to language acquisition (e.g. Fisher, 1996, 2000a; Fisher *et al*., 1994), and it offers unique predictions for early errors in verb interpretation.

First, in common with most recent work in verb semantics (e.g. Jackendoff, 1990; Levin & Rappaport Hovav, 1995; Pinker, 1989), the structure-mapping procedure assumes that semantic structures of verbs are essentially of the same kind as the non-linguistic conceptual structures by which humans represent events. Both demand a division between predicates and arguments, and thus between relations and the entities they relate (e.g. Bierwisch & Schreuder, 1992; Bloom, 1970; Braine, 1992). Second, the structure-matching procedure requires that children learning their first verbs can (a) identify some familiar nouns in fluent speech, and (b) represent these as parts of a larger utterance. Once these achievements are possible, children can construct a rudimentary sentence structure.

These two sets of assumptions have consequences for early sentence comprehension. When children interpret a sentence they link one structure with another. To the extent that these distinct representations – sentence and conceptual – have similar structures, a sentence could provide a rough structural analogy for its interpretation in conceptual terms (e.g. Gentner, 1983). If conceptual and semantic structures are of like kind (the first assumption above), the result of their alignment will be, again roughly, a semantic structure for the sentence.

Gentner and Medina (1998) made a strong case for the central role of structural alignment in many aspects of child and adult cognition. In making comparisons between representations of many kinds (e.g. exemplars within a category, solutions to problems), both children and adults are influenced by the relational structure of the representations being compared. Any two representations, of events, ideas or objects, are complex entities, leaving considerable ambiguity in describing or predicting overall similarity. Structural alignment provides skeletal constraints on comparison, helping to define what aspects of similarity human observers will find compelling (e.g. Goldstone, 1996; Medin, Goldstone & Gentner, 1993).

The structural alignment of sentence structures and relevant conceptual structures should be a relatively simple comparison for young children. Young children are quite practiced at linking nouns with their referents (e.g. Waxman & Markow, 1995; Woodward & Markman, 1998). Once children can do this for more than one noun at a time, the strong referential links between nouns in a sentence and their referents should invite comparison between the sentence and the child's conceptual representation of a scenario in which the referents participate.

The very abstract constraint on interpretation offered by the structure-matching view offers some striking advantages as a mechanism for early verb learning. Most crucially, simple structure mapping would permit variation in syntax-semantics links within and across languages. A structural alignment based on only partially identified sentence structures provides no initial mechanism for distinguishing between different classes of argument-taking predicates like verbs, adjectives and prepositions, or between syntactic arguments and adjunct phrases. This lack of specificity is consistent with the variation found across languages. For example, not all languages have distinct categories of verbs, prepositions and predicate adjectives, with the rough semantic categorization found in English. Thus, some languages use main verbs to convey spatial or attribute meanings (e.g. Choi & Bowerman, 1991; Croft, 1990; Maratsos, 1990), or use words syntactically more like nouns than main verbs to express many action meanings (roughly comparable to the English usage 'give a kiss/hug'; e.g. Danziger, 1998). Languages also vary in which of the participants in a verb's semantic structure are realized as core syntactic arguments, and in the details of the alignment of semantic roles with grammatical positions (e.g. Bowerman, 1990; Jackendoff, 1997; Talmy, 1985; cf. M. Baker, 1997). Significant variation in the inventory of grammatical categories, or the alignment of grammatical with semantic relations, raises grave difficulties for the statement of specific universal correspondences between syntax and semantics. However, the structural alignment of sentence and scene representation described above is sufficiently abstract to permit typological variation in the linking of meaning and syntactic structures, while still providing significant constraint on these links.

The structure-mapping mechanism for syntactic bootstrapping proposed here also makes a unique prediction: nouns in a sentence and arguments of a verb are not the same things. In 'Fred and Ginger danced' or 'Fred danced with Ginger', *dance* has one argument position but two nouns. Via conjunction in the first example, and addition of an adjunct prepositional phrase in the second, these sentences display more nouns than arguments. Before children acquire much of the syntax and function morphology of a particular language, they should systematically misinterpret sentences that have more nouns than they have verb argument positions. Previous research has explored these sentence types extensively, and the overall pattern of results provides some preliminary evidence for the predicted errors in children just at or under 2 years. By 25 months children can interpret intransitive sentences with conjoined subjects correctly (e.g. 'The bunny and the duck are blicking!'; Naigles, 1990). But without multiple morphological clues that the new verb is intransitive, even 28-month-olds can be fooled by a mismatch between number of argument positions and number of nouns in a sentence (e.g. 'Find Big Bird and Cookie Monster gorping!'; Hirsh-Pasek & Golinkoff, 1996). This suggests that number of nouns is a strong early cue for structure-guided interpretation. Further research is under way to test in detail the predictions of early partial-structure matching in sentence interpretation.

In order to acquire a lexicon and a grammar, children must have some system for representing linguistic data before they can identify a fully articulated syntactic structure – before they know, for example, where grammatical subjects are found in a particular language. The intuition explored here is that even very partial representations of sentence structure could influence sentence interpretation. The alignment of partial sentence and conceptual structures would provide a rough distinction between

transitive and intransitive verbs. By exploring the potential uses of partial representations of linguistic data, we can move toward a more complete view of the information sources, constraints and biases required to get the child started in the enormous task of acquiring a language.

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## References

Akhtar, N. (1999). Acquiring basic word order: evidence for data-driven learning of syntactic structure. *Journal of Child Language*, **26**, 339–356.

Akhtar, N., & Tomasello, M. (1997). Young children's productivity with word order and verb morphology. *Developmental Psychology*, **33**, 952–965.

Baker, C.L. (1979). Syntactic theory and the projection problem. *Linguistic Inquiry*, **10**, 533–581.

Baker, M. (1997). Thematic roles and syntactic structure. In L. Haegeman (Ed.), *Elements of grammar: Handbook of generative syntax* (pp. 73–137). Dordrecht: Kluwer.

Bierwisch, M., & Schreuder, R. (1992). From concepts to lexical items. *Cognition*, **42**, 23–60.

Bloom, L. (1970). *Language development: Form and function in emerging grammars*. Cambridge, MA: MIT Press.

Bowerman, M. (1981). The child's expression of meaning: expanding relationships among lexicon, syntax, and morphology. In H. Winitz (Ed.), *Native language and foreign language acquisition* (pp. 172–189). New York: New York Academy of Sciences.

Bowerman, M. (1990). Mapping thematic roles onto syntactic functions: are children helped by innate linking rules? *Linguistics*, **28**, 1253–1289.

Braine, M.S. (1992). What sort of innate structure is needed to 'bootstrap' into syntax? *Cognition*, **45**, 77–100.

Brooks, P.J., & Tomasello, M. (1999). Young children learn to produce passives with nonce verbs. *Developmental Psychology*, **35**, 29–44.

Choi, S. (1997). Language-specific input and early semantic development: evidence from children learning Korean. In D.I. Slobin (Ed.), *The crosslinguistic study of language acquisition, Vol. 5: Expanding the contexts* (pp. 41–133). Mahwah, NJ: Erlbaum.

Choi, S., & Bowerman, M. (1991). Learning to express motion events in English and Korean: the influence of language-specific lexicalization patterns. *Cognition*, **41**, 83–121.

Clark, E. (1996). Early verbs, event types, and inflections. In C.E. Johnson & J.H.V. Gilbert (Eds.), *Children's language, Volume 9* (pp. 61–73). Hillsdale, NJ: Erlbaum.

Croft, W. (1990). *Typology and universals*. New York: Cambridge University Press.

Danziger, E. (1998). Semantics and form class in Mopan Maya: implications for bootstrapping. Paper presented at the Workshop 'Cross-linguistic perspectives on argument structure: implications for learnability', Max Planck Institute for Psycholinguistics, Nijmegen, NL.

Fisher, C. (1996). Structural limits on verb mapping: the role of analogy in children's interpretation of sentences. *Cognitive Psychology*, **31**, 41–81.

Fisher, C. (2000a). From form to meaning: a role for structural analogy in the acquisition of language. In H.W. Reese (Ed.), *Advances in child development and behavior* (pp. 1–53). New York: Academic Press.

Fisher, C. (2000b). Who's blicking whom? Word order in early verb learning. Paper presented at the 11th International Conference on Infant Studies, Brighton, England, July.

Fisher, C., Gleitman, H., & Gleitman, L.R. (1991). On the semantic content of subcategorization frames. *Cognitive Psychology*, **23**, 331–392.

Fisher, C., Hall, D.G., Rakowitz, S., & Gleitman, L.R. (1994). When it is better to receive than to give: syntactic and conceptual constraints on vocabulary growth. *Lingua*, **92**, 333–375.

Garnsey, S.M., Pearlmutter, N.J., Myers, E., & Lotocky, M.A. (1997). The contributions of verb bias and plausibility to the comprehension of temporarily ambiguous sentences. *Journal of Memory and Language*, **37**, 58–93.

Gentner, D. (1983). Structure-mapping: a theoretical framework for analogy. *Cognitive Science*, **7**, 155–170.

Gentner, D., & Medina, J. (1998). Similarity and the development of rules. *Cognition*, **65**, 263–297.

Gillette, J., Gleitman, H., Gleitman, L.R., & Lederer, A. (1999). Human simulations of vocabulary learning. *Cognition*, **73**, 135–176.

Gleitman, L.R. (1990). The structural sources of verb meanings. *Language Acquisition*, **1**, 3–55.

Goldstone, R.L. (1996). Alignment-based nonmonotonicities in similarity. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, **22**, 988–1001.

Grimshaw, J. (1981). Form, function, and the language acquisition device. In C.L. Baker & J.J. McCarthy (Eds.), *The logical problem of language acquisition* (pp. 165–182). Cambridge, MA: The MIT Press.

Hirsh-Pasek, K., & Golinkoff, R. (1996). *The origins of grammar*. Cambridge, MA: MIT Press.

Jackendoff, R. (1990). *Semantic structures*. Cambridge, MA: MIT Press.

Jackendoff, R. (1997). *The architecture of the language faculty*. Cambridge, MA: MIT Press.

Kirk, R. (1982). *Experimental design: Procedures for the behavioral sciences*. Belmont, CA: Brooks/Cole Publishing Company.

Landau, B., & Gleitman, L.R. (1985). *Language and experience: Evidence from the blind child*. Cambridge, MA: Harvard University Press.

Landau, B., & Stecker, D. (1990). Objects and places: geometric and syntactic representations in early lexical learning. *Cognitive Development*, **5**, 287–312.

Levin, B. (1993). *English verb classes and alternations: A preliminary investigation*. Chicago, IL: University of Chicago Press.

Levin, B., & Rappaport Hovav, M. (1995). *Unaccusativity: At the syntax semantic interface*. Cambridge, MA: MIT Press.

Lieven, E.V.M., Pine, J.M., & Baldwin, G. (1997). Lexically-based learning and early grammatical development. *Journal of Child Language*, **24**, 187–219.

Maratsos, M. (1990). Are actions to verbs as objects are to nouns? On the differential semantic bases of form, class, category. *Linguistics*, **28**, 1351–1379.

Medin, D.L., Goldstone, R.L., & Gentner, D. (1993). Respects for similarity. *Psychological Review*, **100**, 254–278.

Naigles, L. (1990). Children use syntax to learn verb meanings. *Journal of Child Language*, **17**, 357–374.

Naigles, L. (1996). The use of multiple frames in verb learning via syntactic bootstrapping. *Cognition*, **58**, 221–251.

Naigles, L., & Kako, E.T. (1993). First contact in verb acquisition: defining a role for syntax. *Child Development*, **64**, 1665–1687.

Naigles, L., Gleitman, H., & Gleitman, L.R. (1993). Children acquire word meaning components from syntactic evidence. In E. Dromi (Ed.), *Language and development* (pp. 104–140). Norwood, NJ: Ablex.

Olguin, R., & Tomasello, M. (1993). Twenty-five-month-old children do not have a grammatical category of verb. *Cognitive Development*, **8**, 245–272.

Pickering, M.J., & Branigan, H.P. (1998). The representation of verbs: evidence from syntactic priming in language production. *Journal of Memory and Language*, **39**, 633–651.

Pine, J.M. Lieven, E.V.M., & Rowland, C.F. (1998). Comparing different models of the development of the English verb category. *Linguistics*, **36**, 807–830.

Pinker, S. (1989). *Learnability and cognition*. Cambridge, MA: MIT Press.

Talmy, L. (1985). Lexicalization patterns: semantic structure in lexical forms. In T. Shopen (Ed.), *Language typology and syntactic description. Volume 3: Grammatical categories and the lexicon* (pp. 57–149). New York: Cambridge University Press.

Tomasello, M. (1992). *First verbs*. New York: Cambridge University Press.

Tomasello, M. (2000). Do young children have adult syntactic competence? *Cognition*, **74**, 209–253.

Trueswell, J.C., & Kim, A.E. (1998). How to prune a garden path by nipping it in the bud: fast priming of verb argument structure. *Journal of Memory and Language*, **39**, 102–123.

Waxman, S.R., & Markow, D.B. (1995). Words as invitations to form categories: evidence from 12- to 13-month-old infants. *Cognitive Psychology*, **29**, 257–302.

Woodward, A.L., & Markman, E.M. (1998). Early word learning. In D. Kuhn & R.S. Siegler (Eds.), *Handbook of child psychology, Volume 2: Cognition, perception, and language* (pp. 371–420). New York: Wiley.

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