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Children use syntax to learn verb meanings*

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ABSTRACT

Verb learning is clearly a function of observation of real-world contingencies; however, it is argued that such observational information is insufficient to account fully for vocabulary acquisition. This paper provides an experimental validation of Landau & Gleitman's (1985) syntactic bootstrapping procedure; namely, that children may use syntactic information to learn new verbs. Pairs of actions were presented simultaneously with a nonsense verb in one of two syntactic structures. The actions were subsequently separated, and the children (MA = 2;1) were asked to select which action was the referent for the verb. The children's choice of referent was found to be a function of the syntactic structure in which the verb had appeared.

INTRODUCTION

How do young children learn word meanings? While the extralinguistic environments (scenes observed while speech is heard) must play a role, real-world scenes are often uninformative or misleading, and the exact referent of a novel word is often uncertain (Quine, 1960). For example, the child who is learning what *cat* means may indeed be observing a 'cat', but she is also probably observing an 'animal', 'blackness' (or other colour), a 'long tail', and a 'cat-in-the-specific-context-of-the-mat'. Given the plurality of interpretations for the word *cat*, how does she choose the correct one? This induction problem of word learning is further fuelled by the dearth of negative evidence available to or used by very young children (Pinker, 1984, 1989).

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Responses to the induction problem have involved postulating certain constraints (e.g. Contrast or Mutual Exclusivity (Clark, 1987; Markman, 1987), and Object Scope (Golinkoff, Bailey, Wenger & Hirsh-Pasek, 1989)) that provide the child with some foci with which to interpret her environment. Most of these constraints, however, have been designed primarily for the acquisition of nouns (but see Taylor & Gelman (1988) for a discussion of adjectives). This paper attempts to broaden the base of this research by considering the induction problem for the acquisition of VERBS, and by validating experimentally a recently proposed principle for verb learning (Landau & Gleitman, 1985; Gleitman, Gleitman, Landau & Wanner, 1987), the Syntactic Bootstrapping hypothesis.

The induction problem of word learning exists for verbs as well as for nouns. For example, the child who hears *oh! bringing!* while observing the action of 'bringing' (for example, Adam bringing the truck to Mom), may also be observing 'coming/walking' (Adam is coming/walking to Mom with the truck, Adam and the truck are coming to Mom), 'getting/taking' (Mom is getting/taking the truck from Adam), 'playing' (Adam is playing with the truck), and so forth. As with the case of nouns mentioned above, it is puzzling how the child could choose among these several plausible and salient ways of interpreting the situation so as to arrive at the right conjecture about the meaning of the verb in the utterance heard.

The case of verbs, however, gets even more complicated. Studies in lexical semantics (e.g. Fillmore, 1968; Talmy, 1975, 1980; Jackendoff, 1983; Levin, 1985) have suggested that many semantic components (e.g. causation, direction or location of action, manner of action, etc.) contribute to the meaning of a verb. Some of these components are marked in the surface structure, but others are incorporated, or CONFLATED, into the actual verb. The problem for verb learning is that languages differ as to their basic conflation patterns for verbs. Thus, when a child observes a scene and hears a verb, she cannot know *a priori* which components of the scene are lexicalized in the verb, and which are represented by affixes, prepositions, or adjuncts. For example, in English the component of causation is usually conflated with the verb, while in Turkish it appears as a suffix (from Aksu-Koç & Slobin, 1985):

(1) Su -nu *kal- dir- sana.*
that ACC get:up cause IMP.
Lift that up

The learner cannot know whether *lift* means 'cause to get up' or just 'get up', solely from her observation of the context in which the verb occurs. Yet because of the crosslinguistic variation, neither can the child assume, say, that when causation is evident in the environment, it is encoded in the verb.

In fact, this crosslinguistic variation has figured prominently in an account of the relatively later appearance of verbs than nouns in children's vocabularies; see Gentner (1982) for details and elaboration.

In sum, because of the plurality of choices the real-world scene provides, verb learners must be using more information than is present in the observed scene. In addition, because of the cross linguistic variation in the assignment of relational terms, it would seem that the verb learner should take into account the surface structures (i.e. number and arrangement of NP arguments, inflections, and adjuncts) in which the verbs appear. This is the tack taken by Landau and Gleitman's theory of syntactic bootstrapping.

Landau & Gleitman (1985) and Gleitman *et al.* (1987) have proposed that children exploit certain regularities between verb meaning and sentence structure to narrow down the possible meanings of specific verbs. In this way, syntactic bootstrapping would enable the child to choose between the several interpretations allowed by observation. This theory depends on three factors: that regularities between syntax and verb semantics exist, that children are aware (implicitly) of the regularities, and that children can use them to make conjectures about meaning. There is evidence for each of these factors.

Many linguists and psychologists have theorized that words which differ systematically in meaning also differ systematically in the kind of sentence structures they appear in (e.g. Chomsky, 1981; Kaplan & Bresnan, 1982). The regularities between syntax and verb semantics have been the subject of extensive investigations (e.g. Jackendoff, 1983; Talmy, 1975, 1980; Grimshaw, 1983; Levin, 1985; Fisher, Gleitman & Gleitman, 1989). These investigations have suggested, for example, that verbs which take PPs whose prepositions indicate direction (e.g. *to, towards, away from, along, across*, etc.) usually encode motions rather than states, that verbs which take sentential complements usually involve mental rather than physical states, and that verbs which take direct objects (i.e. appear in transitive frames) often involve a specifically causal relation. None of these relations between syntax and verb semantics is categorical; however, they appear to be stable enough to support conjectures from one field of knowledge to the other.

The results of past research also suggest that children know (implicitly) some of these regularities between their syntactic and semantic databases. Bowerman (1974, 1977, 1983) has observed in the spontaneous speech of her own young children that they will sometimes say *I'm gonna fall this on her* when they mean 'I'm gonna cause this to fall on her'. Apparently, the children had conjectured a new verb (*cause-to-fall*), decided on analogy with verbs like *break* and *move* that it would be used without phonological modification, and then exploited the transitive–causative relation to select a sentence frame for it (the transitive). This evidence (see also Maratsos,

Gudeman, Gerard-Ngo & DeHart, 1987; Pinker, 1989; Gropen, Pinker, Hollander & Goldberg, 1989) suggests that children can make predictions about sentence structure, given a particular novel verb meaning.

Syntactic bootstrapping predicts that the opposite can also occur: that children can conjecture novel MEANINGS for verbs, based on the presentation of novel SYNTACTIC FRAMES. A recently study by Naigles, Gleitman & Gleitman (1989) supports this prediction for the case of familiar verbs. In that study, 2-, 3-, and 4-year old children were presented with ungrammatical sentences to act out; these contained known verbs in prohibited frames (e.g. **the zebra goes the lion.*). The question asked was whether the children could use the information encapsulated by the frame (e.g. causation for the transitive frame) to extend the meanings of the verbs placed in them. The results suggested the affirmative: the children altered the meanings of the verbs in a systematic manner, using causative actions for verbs in transitive sentences, and non-causative actions for verbs in ungrammatical intransitive sentences (e.g. **The zebra brings to Noah.*). This shows that preschoolers, at least, hold the transitive/causative, intransitive/non-causative relation to be symmetric, and indicates more generally that verb extension can proceed from form to meaning as well as from meaning to form.

The purpose of the present experiment was to test the Syntactic Bootstrapping hypothesis even more directly. Since the verbs used in the Naigles *et al.* experiment were common ones, the children were reinterpreting familiar verbs on the basis of novel syntactic frames, but were not actually LEARNING verbs. This experiment was designed to investigate whether young children can in fact use the syntax to constrain and focus verb meanings in their interpretations of novel scenes and novel verbs. In this experiment, the child was presented with two novel actions – one causative, the other non-causative – but only one novel verb. The child's job was to figure out which action represented the new verb. The question asked was whether the sentence frame in which the verb was presented would determine which action was chosen for the verb.

METHOD

This experiment utilized the preferential-looking paradigm recently developed by Golinkoff & Hirsh-Pasek (Golinkoff, Hirsh-Pasek, Cauley & Gordon, 1987), which was adapted from a method devised by Spelke (1976) to study intermodal perception in infants. This is a more sensitive language comprehension paradigm than the more common 'acting-out' method, because it simply requires the child to LOOK at one of two simultaneously presented video events. If the utterance the child hears is understood correctly (i.e. according to the rules of English), then she would presumably focus on the one scene that is consistent with that utterance. If the utterance

is not understood, the child would presumably look randomly at either scene (assuming neither is particularly salient). Golinkoff and Hirsh-Pasek have already shown this paradigm to be revealing for investigations of the beginnings of syntactic knowledge in children aged 1;1 to 2;0 (Hirsh-Pasek, Golinkoff, deGaspe-Beaubien, Fletcher & Cauley 1985, Golinkoff *et al.* 1987); hence, it seems well-suited for the study of lexical acquisition in young children.

Subjects

The subjects were 24 children, 12 males and 12 females, all raised in English-speaking homes. They were between the ages of 1;11 and 2;3, with a mean age of 2;1. Their mean productive vocabulary was 240 words (out of a possible 354 on Rescorla's (1985) vocabulary checklist). Seventeen of them had produced (by maternal report) three-word or longer utterances, while seven were still in the two-word stage. This period in development, just around two years of age, is a crucial one for language learning, as it marks when most children begin producing words in combinations, and when their vocabulary, especially their vocabulary of verbs, begins to skyrocket in number. Since it represents a time when children are learning many verbs, it seems appropriate to ask if they can use syntactic frames for this purpose.

Apparatus

The basic set-up is shown in Fig. 1. The child was seated on the mother's lap and observed two different, simultaneously presented, video events on two side-by-side video monitors. Between the two monitors, which were separated by 12 inches, an auditory speaker played a message that matched only one of the video events, or scenes. On top of the speaker was a ten-watt light bulb that lighted between trials to attract the child's attention. Children were placed two feet back from the centre of the two video displays. The child's visual fixation to the two monitors was recorded by a hidden observer, who was blind to the experimental condition. The mother was also blind to the experimental condition, as she wore a visor over her eyes while in the testing room.

The stimulus displays were colour videotapes, which were made with a Newvicon 3150 camera filming against a white wall. Inter-trial intervals were created by inserting three seconds of black tape. Each tape was prepared as one of a pair. Thus, tapes in a pair had the identical structure, down to the number of frames per episode. This level of precision enabled the synchronous operation of tapes, such that neither tape began before the other in a pair, and such that both tapes had an equal number of episodes of action per trial. the auditory stimuli were then dubbed onto one channel of the final version

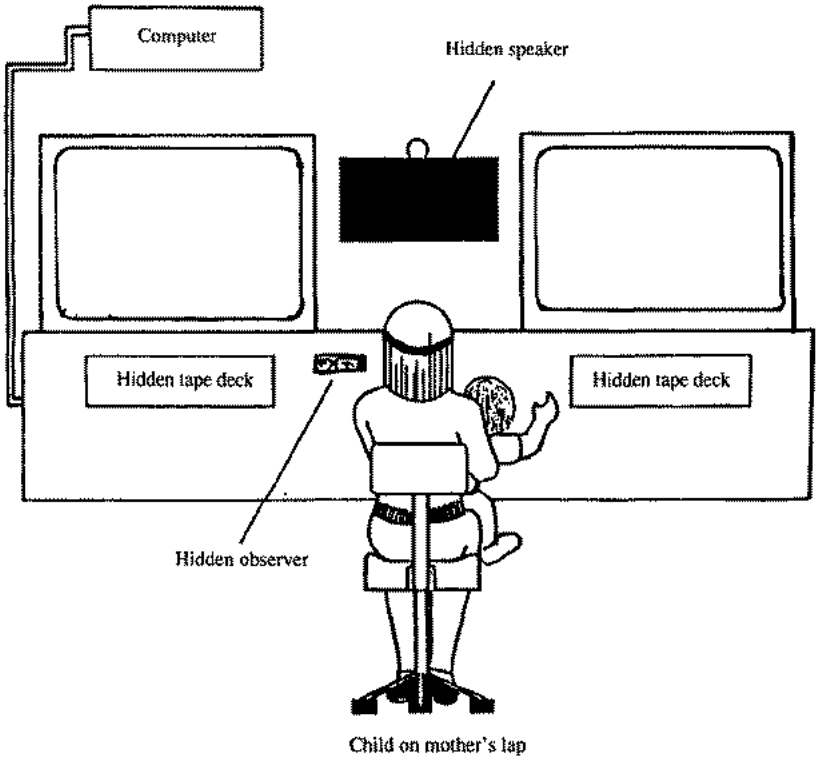

Fig. 1. Experimental set-up of the preferential looking paradigm.

of the tapes. On the other channel, a 1 kHz tone was dubbed on at the beginning and end of trial segments to permit the computer to record trials. These tones were read by a tone decoder which interfaced with the computer.

Stimuli and design

A schematic depiction of the videotapes and the audio match is presented in Fig. 2. The left and right columns indicate videos, while the centre column indicates the audio. The audio of a female voice was first heard during three seconds of black tape before each presentation of a pair. The audio was then repeated as the scenes were presented for 6 seconds each. First, an introductory passage familiarized the subjects with the situation and the characters (see Appendix for the complete sequence), and then, the test of syntactic bootstrapping began. The crucial sequence was as follows. In trial 5, one screen presents a Multiple Scene – two actions going on simultaneously, performed by the same two actors. One of the actions is causative (the duck

forcing the rabbit into an odd bending position), and the other is non-causative (the same duck and rabbit making arm gestures). The accompanying audio presents a novel verb – *gorp* – in a sentence. This verb is either in a transitive frame, e.g. *Look! The duck is gorping the bunny* or in an intransitive frame, e.g. *Look! The duck and the bunny are gorping*. This presentation of two novel actions and one novel verb (repeated twice: once on the other screen and once on both screens, trials 6 and 7) comprises the 'teaching' phase of the experiment.

Next, the two actions are separated into Single Action Scenes (trial 8 in Fig. 2): one screen shows ONLY the causative action of the duck forcing the rabbit into the odd bending position, while the other screen, displayed at the same time, shows ONLY the duck and the rabbit making the arm gestures. This control trial (whose audio is *Oh! they're different now!*) serves two purposes. First, it permits the child to inspect the two alternatives visually before the directive audio is introduced (see below). Secondly, by coding visual fixation during the pair of events without a directive audio, a measure of stimulus salience was obtained. In order for the test data to be interpreted unequivocally, neither member of a silent pair should receive significantly more attention.

Finally, the test trials (trials 9 and 10) are presented. The Single Action Scenes appear again, paired with the test audios, *Where's gorping?* or *Find gorping now!* These trials test what the children learned from the teaching phase.

This pattern of teaching and testing was repeated across four nonsense verbs for each of the subjects (see Table 1 for the specific actions). Half of the children heard each verb presented in the transitive audio (e.g. *The duck is gorping the bunny!*), and the other children heard each verb presented in the intransitive audio (e.g. *The duck and the bunny are gorping!*). The side of the matching screen was counterbalanced across subjects, by varying the placement of the tapes in the video tape decks. The side of the matching screen was also counterbalanced within subjects so that the match occurred equally on the left and right sides.

Dependent variables

Each trial was coded for one dependent variable: total visual fixation time to the matching and non-matching screens (measured in hundredths of a second). Since the audio began while the screens were blank between trials, trials were coded from the point at which the infant looked at the central light for more than 0·3 seconds. Trials where the infant did not return to the centre light for a minimum of 0·3 seconds were excluded. Using this criterion, an average of one trial out of eight was excluded from further analysis.

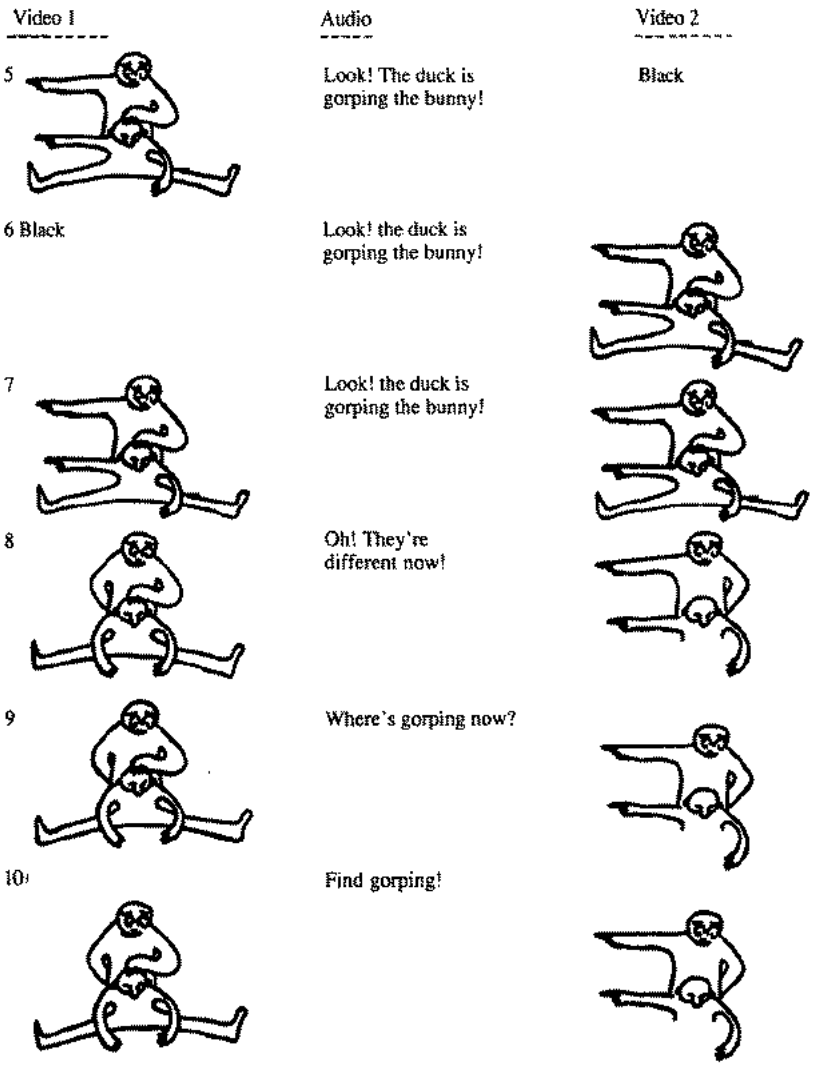

Fig. 2. Crucial sequence on videotapes, showing Teaching (trials 5–7), Control (trial 8) and Test (trials 9 and 10) phases. The actual characters were actors dressed in duck and rabbit costumes.

Procedure

Subjects and their parents were first interviewed in the playroom by the experimenter for an average of 15 minutes. At this time, the parent filled out a brief language questionnaire (Rescorla, 1985), and was given the visor to wear. The experimenter then escorted the parent (usually the mother) and

TABLE 1. *Causative and non-causative actions associated with each verb*

Verb	Causative	Non-causative
Gorp	Duck forces rabbit into bending position	Duck and rabbit flex own arms
Blick	Rabbit makes duck pat duck's head	Rabbit and duck lift own legs
Krad	Rabbit makes duck tilt duck's head	Duck and rabbit make arm circles
Dax	Duck lifts rabbit's leg	Duck and rabbit cover own eyes with own arm

child to the testing room. The mother was told to place the child on the centre of her lap facing forward. The experimenter then turned on the presynchronized videotapes and left the testing room. During a trial, children generally scanned back and forth across both monitors sampling the contents of both screens. The observer hidden behind the screens (blind to the experimental condition) pressed hand-held buttons for the duration of a child's fixation to the left or right screen. Data from the button presses were collected and tabulated by an Apple IIe computer.

RESULTS

The main question concerned the within-subjects factor of the screen: did the children fixate longer at the screen that matched what they heard? That is, did the children who heard the novel verbs presented in the TRANSITIVE audio during the teaching phase choose to focus on the screen showing the CAUSATIVE action during the test phase? Likewise, did the children who heard the novel verbs presented in the INTRANSITIVE audio during the teaching phase choose to focus on the screen showing the NON-CAUSATIVE action during the test phase? A Preliminary Analysis (see Fig. 3) suggests that they did. Inspection of this figure indicates that the matching screen received more visual fixation than the non-matching one. An (Audio × Match) analysis of variance revealed a significant main effect of matching versus non-matching screen ($F(1, 22) = 14{\cdot}83$, $p = 0{\cdot}001$), and no significant interactions.

This analysis indicates that across both audio conditions the matching screen received significantly more visual fixation than the non-matching screen. Thus, the children who heard the Transitive Audio while watching the combined actions (Multiple Scene) in the teaching phase looked significantly longer at the CAUSATIVE action when the single action (Single Scene) test trials came on, and the children who heard the Intransitive Audio while watching the combined actions looked significantly longer at the NON-CAUSATIVE action when the test trials came on. The data of the individual subjects indicate that twenty of the twenty-four children exhibited this pattern (ten out of twelve in each audio condition).

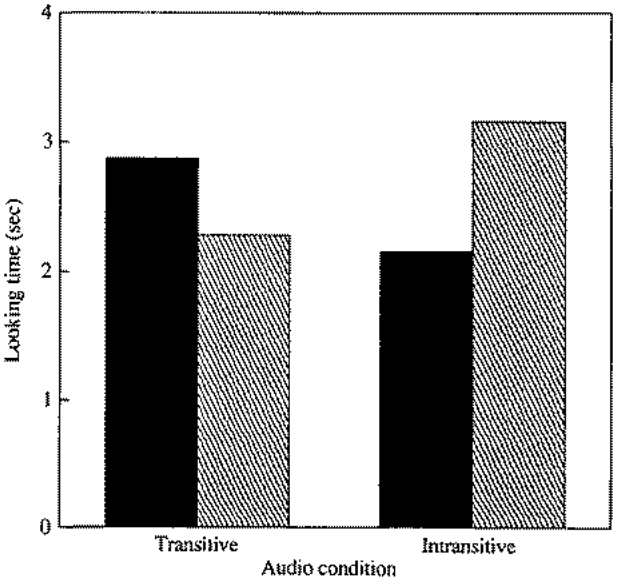

Fig. 3. Mean visual fixation during the test trials to the causative and non-causative actions, for the Transitive and Intransitive Audio conditions. ■, Causative action; □, non-causative action.

The Primary Analysis takes into account the children's visual fixation preferences both during the control trials and during the test trials. This is because it is possible that, given two novel actions and one novel verb, children have an INITIAL bias to label one of the actions with the novel verb regardless of the syntactic frame in which the verb was presented. Thus, the subjects' action preferences during the test trials (when they were told to *find gorping*) were compared with their own preferences during the control trial (when their initial action – and so screen – preference would presumably be dominant), and difference scores were computed for each subject. For those who heard the transitive audio, the difference scores were computed by subtracting looking time to the non-causative (non-matching) screen from looking time to the causative (matching) screen for both the control and test trials. For those who heard the intransitive audio, the difference scores were computed by subtracting looking time to the causative (non-matching) screen from looking time to the non-causative (matching) screen.

The results are presented in Fig. 4, which shows that the children's preference for the matching screen is greater for the test trials than for the control trials, for BOTH syntactic frames. An (Audio × Sex × Counterbalance Pattern × Verb × Preference Difference) analysis of variance revealed a significant main effect of preference difference (in the control versus the test

trials) ($F(1, 16) = 12{\cdot}85$, $p = 0{\cdot}003$). There was no significant interaction of preference difference and audio, which confirms that the difference between control and test trials is found in both the transitive AND the intransitive audio conditions, and there were no significant interactions of preference difference and verb, which indicates that the preference for the matching screen was obtained for all four novel verbs.

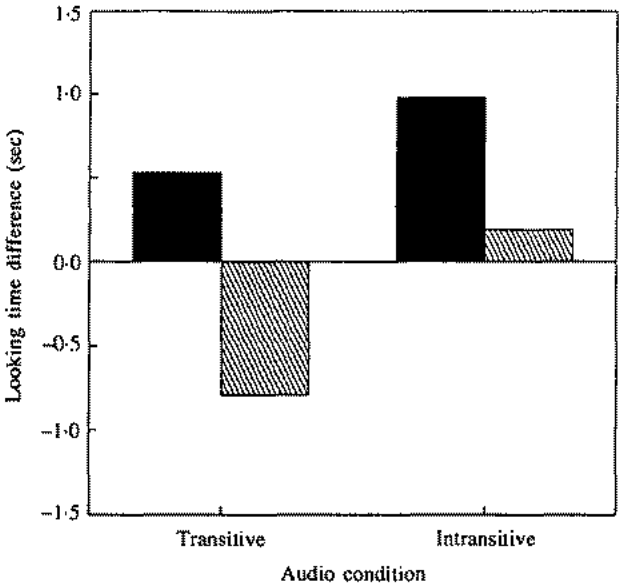

Fig. 4. Mean visual fixation preference for the matching screen (causative in the Transitive Audio condition and non-causative in the Intransitive Audio condition) during the test (■) and control (▨) trials.

Before discussing some consequences of these results, an artifactual explanation for the effect obtained with the intransitive audio can be eliminated. This involves the specific form of the intransitive structure which was presented; namely, as a conjoined or coordinate subject (e.g. *the duck and the bunny* are gorping). The rationale for using the co-ordinate subject was to include both characters in a simple sentence; however, it is possible that the coordinate noun phrase was what motivated the children to look for the scene where both characters were doing the same thing. This still requires some syntactic facility: one must realize that the action described by the predicate is applicable to *both* characters in subject position (i.e. that *the duck and the bunny are gorping* indicates *the duck is gorping and the bunny is gorping*). However, it is important to know whether the co-ordinate subject is the only type of intransitive frame that could yield this result.

One condition of a larger study performed by Hirsh-Pasek, Naigles, Golinkoff, Gleitman & Gleitman (1988) addresses this issue using the same paradigm but slightly different stimuli. The directing audio for the non-causative scenes (which again showed both characters performing the same action) had a different intransitive structure: only one character occupied the subject position, and the second character was represented as the object of the preposition *with* (e.g. *Big Bird flexes with Cookie Monster*). The age of the subjects was slightly older (mean age = 2;4 months), but the procedure, dependent variables, and analyses were the same as in the present study (see Hirsh-Pasek, *et al.* 1988, for details). In brief, even though a different form of the intransitive structure was used, the same results were obtained. This result corroborates the current study, and shows that the effect of the intransitive frame cannot be solely attributed to conjoined or single NPs in the input sentence; that is, the co-ordinate subject is not necessary to direct children's attention to non-causative actions performed by two characters. Since BOTH forms of the intransitive elicit the same response, the effect appears to be based on the correlation between verb meaning and the syntactic frame itself.

DISCUSSION

This paper began with the question, How are the meanings of words, and more specifically verbs, learned by children? The syntactic bootstrapping hypothesis proposed by Landau & Gleitman (1985) (see also Gleitman *et al.* 1987; Naigles *et al.* 1989) suggested that one source of information about verb meanings resides in the syntactic frames in which the verbs are presented. The results of this experiment provide strong support for this hypothesis, as they show that the structure of the input sentence can focus the child's interpretation of the scene, and so influence her selection of the action in the scene that the verb refers to. Specifically, the children who heard novel verbs in transitive frames seemed to believe (as measured by their visual fixation) that the verbs referred to the causative actions, while the children who heard the same novel verbs in intransitive frames seemed to believe that the verbs referred to the non-causative actions.

These results extend the findings of the Naigles *et al.* (1989) study in two important ways. First, if syntactic bootstrapping is to be a significant force in verb learning, it should be operative for children when they encounter NEW verbs. Indeed, the children in this study were able to use the syntax to determine the meanings (or at least the referents) of novel verbs; this seems closer to the actual verb learning scenario than extending the meanings of familiar ones. Secondly, syntactic bootstrapping should be operative early in the acquisition process: a cause, not just an effect, of verb learning. We see that the subjects in the present experiment were younger than any of those

studied by Naigles *et al.*: at just two years of age, they are constantly engaged in the learning of new verbs (Brown, 1973). Thus, this study provides DIRECT evidence that sentence structure is a powerful source of information for verb learners who must infer the referents of novel verbs. Given this initial validation of syntactic bootstrapping, let us consider more closely the level of syntactic and semantic analysis the children have exhibited.

Level of syntactic parsing

Syntactic bootstrapping presupposes some amount of syntactic knowledge; namely, the ability, at least, to parse a sentence into a predicate and its arguments. The sentences used in this experiment were quite simple: the syntactic form of the transitive frame was [NP V NP], while the syntactic form of the intransitive frame was [NP and NP V]. It would be interesting to know, though, at what level of syntax the children were really parsing these sentences, i.e. the input audios could have been parsed as surface structures composed of hierarchically organized NPs and VPs, or as particular combinations of predicates and arguments, or perhaps as more pragmatically based topic–comment structures. The level of parsing has consequences for the level of linguistic sophistication proposed for the children, and for the precise format of their meaning–form relation.

In the current experiment, it is simply unclear just what structural representations the children were creating: each of the above is a possibility. It is certainly possible that they were working with a surface parse tree; several researchers (e.g. Pinker, 1984; Borer & Wexler, 1987; Gleitman *et al.* 1987) suggest that even children's initial sentential structures are abstract and hierarchical. However, straightforward evidence for the existence, for example, of the grammatical form classes of noun and verb does not appear until the age of three (Valian, 1986). Given the dearth of evidence on one- and two-year- olds' syntactic sophistication, it would be premature to assume that the 25-month-olds in this study were operating with full-blown syntax. As stated above, it is not even necessary that they do so. What is clear is that they consistently and systematically distinguished the two audio frames, and made conjectures about meaning based on these distinctions.

Level of semantic analysis

Syntactic bootstrapping proposes that children use sentence structure as one source of information to infer the meanings of verbs. It was claimed above that the actions of *gorping*, *blicking*, *kradding* and *daxing* in this study were considered to be specifically causal when the novel verbs were in transitive frames, and non-causal when they were in intransitive frames, based on the transitive–causative, intransitive–non-causative correlation in English.

However, because (as stated in the Introduction) these meaning–form correlations are not categorical, the question of what precisely were the meanings the children learned warrants a closer look.

The transitive frame–causative meaning correlation is a common one in English; it is perhaps best exemplified when verbs such as *break*, *burn*, *sink*, and *move* are used transitively:

(2) Adam burns the candle.

Burn in a transitive frame clearly implicates the notion of causation: Adam is *causing* the candle to burn. The subject of the sentence acts as the agent of the causal relation, while the direct object acts as the experiencer of the causal relation. This correlation with causation is by no means absolute, though: transitive sentences exist which do not involve causation at all. When verbs such as *eat*, *sew*, *see*, *paint*, and *watch* are used transitively, as in

(3) Adam eats the fish.

they do not implicate any particularly causal type of relation. Sentence (3) does not mean Adam causes the fish to eat. In contrast to the causative transitive in (2), the subject of the so-called unergative transitive (Perlmutter, 1978; Levin, 1985) in (3) acts as the experiencer of the relation of eating, while the direct object acts as the patient. The assignment of semantic roles to the nominal arguments is different in the two kinds of transitive frames, and this difference is reflected in the meanings assigned to the verbs which appear in them.

The causative–unergative ambiguity with the transitive frame is what makes it difficult to determine the meanings the children in this study inferred for the novel verbs. The causative action that was paired with *gorp* could have been interpreted as 'cause to push someone over into a bending position'; however, a more general interpretation, such as 'hold onto someone while he bends', is also possible. The latter interpretation omits the explicit causal component and would be captured by an unergative rather than causative verb. Data relevant to this question come from Bowerman's (1983) corpora of transitive overgeneralizations and Naigles *et al.*'s (1989) study of preschoolers' comprehension of novel (ungrammatical) transitives; both analyses suggest that the causative interpretation is primary for novel transitives.

Considering only the present study, though, the complexity of the scenes and actions that served as stimuli render one unable to determine which PRECISE meaning (causal or 'acting-on') was inferred for the transitive frame. In order for us to determine more precisely the meanings the children posited based on syntactic evidence, more specific pairs of actions will need to be presented to the children. For example, children could be asked to select between a blatantly causal action such as 'a duck forcing a rabbit to squat'

and an acting-on relation such as 'the duck stroking the rabbit', when given a verb in a transitive frame. Their choice of action might reveal how refined is the meaning they inferred, and in consequence how specific is the semantic influence of the transitive frame.

The same ambiguity exists for the intransitive frame: it is not the case that all verbs in intransitive frames express specifically non-causal meanings. As shown in sentenee (4), when *burn* is in an intransitive frame, its meaning is clearly non-causal: the candle is burning of its own accord. However, the intransitive form of *eat* in (5) does not implicate any different kind of eating than the transitive form did in (3); the object eaten is still assumed, but its surface expression is not necessary. Causation is not a relevant component in either the transitive or intransitive form of *eat*.

(4) The candle burns.
(5) Adam eats.

Given, then, that there exist intransitive verbs that are not specifically non-causal, we may ask again what meanings the children in the present study inferred for the novel verbs. The non-causative action that was paired with *gorp* could have been interpreted as 'flex one's own arm', a non-causal action; however, another possible interpretation is 'perform a symmetric action with someone, using one's arm'. This focuses attention on the symmetry of the actions, not on their lack of causation, and would probably be captured by an *eat*-type verb. Again, the stimuli used in the current study were not specific enough to allow us to distinguish between these possibilities; a study similar to the one described above for transitive frames could also probe more deeply the meanings which the children conjectured for verbs in intransitive frames.

One might well wonder, at this point, whether these same ambiguities with the transitive and intransitive frames end up hampering rather than helping the verb learner. How is a child to know, when she hears a verb in a transitive frame, whether the action is to be interpreted as specifically causal or more generally 'acting-on'? One answer, as Landau & Gleitman (1985) (see also Jackendoff, 1985) have pointed out, might lie in the SET of frames that a verb appears in. That is, it is not one presentation of verb-in-frame that yields its interpretation; this is gleaned from the presentation over time of the verb in its particular set of syntactic frames. For example, in order to determine whether or not a verb involves causation, a verb learner might want to know not only whether it appears in transitive frames, but also how it appears in intransitive frames; that is, how it alternates between the two. (Clearly, there also exist English verbs which are obligatorily either transitive or intransitive, and hence do not alternate. The following suggestion concerning the use of the transitive/intransitive alternation for determining causality does not claim to be exhaustive.) One transitive/intransitive alternation is shown in

(2) and (4) above: the direct object in the transitive frame shifts to subject position in the intransitive frame. This is the alternation that expresses the presence or absence of causation; it has something of the status of a productive rule (Aronoff, 1976; Bowerman, 1983; Pinker, 1989; but see also Maratsos *et al.* 1987). The other transitive/intransitive alternation that verbs may participate in is shown in (3) and (5) above: the subject of the transitive frame remains the subject of the intransitive. This alternation does not involve causation at all. By hypothesis, then, observation of how a verb alternates between transitive and intransitive frames would provide the child with more precise information concerning whether or not the verb involves causation.

CONCLUSION

This study has shown that 2-year-old children conjecture different meanings for novel verbs depending on whether they are presented in transitive frames or in intransitive ones. Transitive frames appear to implicate actions which are at least 'acting-on' and perhaps even specifically causal, while intransitive frames implicate actions which are non-causal or perhaps symmetric. The sentence structures, then, were used by these very young children as evidence about the interpretation of a novel verb. While these results provide an initial validation of the syntactic bootstrapping hypothesis, several interesting questions remain. For example, nothing has been said about how the form–meaning correlations, insofar as they differ across languages, are acquired; this is clearly a crucial point for a theory which presupposes some linguistic knowledge to begin with. Secondly, detailed work need to be done to determine more precisely the meanings that children infer from syntax. Finally, this research (and much of the acquisition research concerned with syntax–semantics relations) has focused on the transitive–causative link in English; a challenge for the future will be to show that other elements of verb meaning can be learned via syntactic evidence.

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APPENDIX

The structure of the stimulus videotapes for the verb 'gorp'.

Tape 1	Audio	Tape 2
	Character identification segment	
1. Duck waves	Where's the duck?	Rabbit waves
2. Duck waves	Where's the bunny?	Rabbit waves
3. Duck waves	Find the bunny!	Rabbit waves
4. Duck waves	Look at the duck!	Rabbit waves
	Syntactic bootstrapping segment	
5. The duck is forcing the rabbit into a bending position; both are making arm gestures	Look! The duck is gorping the bunny!	Black
6. Black	Look! The duck is gorping the bunny!	Duck is forcing the rabbit into a bending position; both are making arm gestures
7. The duck is forcing the rabbit into a bending position; both are making arm gestures	Look! The duck is gorping the bunny!	Duck is forcing the rabbit into a bending position; both are making arm gestures
8. The duck is forcing the rabbit into a bending position	Oh! They're different now!	The duck and the rabbit are making arm gestures
9. The duck is forcing the rabbit into a bending position	Where's the gorping now?	The duck and the rabbit are making arm gestures
10. The duck is forcing the rabbit into a bending position	Find gorping!	The duck and the rabbit are making arm gestures