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Input to Verb Learning: Evidence for the Plausibility of Syntactic Bootstrapping

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The theory of *syntactic bootstrapping* proposes that children use the syntactic frames in which verbs are presented as a source of information about their meaning. The purpose of this study was to investigate the extent to which maternal type and diversity of verb frames are consistent with the requirements of that theory. The uses of 25 common verbs in the speech of 57 mothers to their 1- to 2-year-old children were tabulated and parsed for syntactic frame. Analyses revealed 2 major findings concerning the use of verbs in child-directed speech: (a) Verbs in different semantic categories appear in different syntactic environments, and (b) individual verbs are distinguished by the set of frames in which they appear. These findings support the plausibility of the syntactic bootstrapping hypothesis by demonstrating that children's input provides the structural cues to verb meaning that the syntactic bootstrapping procedure requires.

When children hear a sentence with an unfamiliar verb, they can look to the extralinguistic context for clues to the meaning of that verb. However, as Gleitman and her colleagues have argued (Gleitman, 1990; Landau & Gleitman, 1985), it is unlikely that the extralinguistic context will unambiguously reveal a single meaning. For example, the extralinguistic context surrounding the utterance "Are you bringing me the doll?" is likely to be consistent with interpreting the verb in that sentence to mean *hold, carry,* or *walk,* as well as *bring.* It is likely, then, that children make use of additional information in acquiring the meanings of verbs. In this example, another potential source of information about the meaning of *bring* comes from the syntax of the sentence in which it appears. In this utterance, "bring" is followed by an indirect object and then a direct object, suggesting that *bring* is a verb of transfer (because transfer involves both the thing transferred and the person to whom it is transferred) and thus eliminating the meanings of *hold, carry,* and *walk* from contention. According to the theory of *syntactic bootstrapping* (Fisher, Hall, Rakowitz, & Gleitman, 1994; Gleitman, 1990; Naigles, 1990; Naigles, Fowler, & Helm, 1992; Naigles, Gleitman, & Gleitman, 1993; Naigles & Kako, 1993), children use the syntactic frames in which verbs appear to narrow down or constrain the possible interpretations allowed by the extralinguistic circumstances.

There are, so far, two main types of evidence for syntactic bootstrapping. First, a variety of research in linguistics and psychology has provided evidence that verb meaning and verb syntax are related (Bowerman, 1983; Fisher, Gleitman, & Gleitman, 1991; Jackendoff, 1983, 1990; Levin, 1993; Naigles et al., 1992; Pinker, 1989). For example, prepositional phrases tend to co-occur with motion verbs and sentence complements (Ss) tend to co-occur with mental state verbs. Thus, the example of *bring* above is not an isolated one, but rather is one illustration of a more general phenomenon; to wit, verbs with different meanings have different syntactic privileges of occurrence. Second, experimental research has demonstrated that young children can make use of syntax as a clue to verb meaning (Naigles, 1990; Naigles & Kako, 1993). When 2-year-olds are presented with a nonsense verb, their interpretation of that verb differs systematically depending on the sentence frame in which the verb was presented.

As the above discussion suggests, the theory of syntactic bootstrapping asserts that children use the structural characteristics of utterances in acquiring verbs. Thus, children are presumed to be sensitive to the ordering patterns (frames) that operate on such grammatical categories as direct and indirect objects, prepositional phrases (PPs), and sentence complements. Recent research in children's production and comprehension (Bloom, 1990; Hirsh-Pasek & Golinkoff, 1991) has demonstrated that one- and two-word speakers are sensitive to word order. It has been more difficult to establish that young children's linguistic categories are grammatical ones, as opposed to semantic–pragmatic ones such as patient, recipient, and goal (cf. Pinker, 1984, and Tomasello, 1992). However, semantic categories have been argued to be maximally coextensive with grammatical ones in children's early input; therefore, correlations between verb meaning and verb frames based on semantic–pragmatic units should be equivalent to the correlations described earlier, which involve verb frames based on grammati-

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cal units. Thus, although the clearest expositions of the relations between verb meanings and their accompanying frames are based on grammatical categories, syntactic bootstrapping could still operate if the frames that distinguished verb meanings were based on semantic–pragmatic categories.

Although it has been demonstrated that verb semantics and verb syntax are linked and that children can use syntax as a basis for inferring verb meaning, it remains to be demonstrated that syntactic bootstrapping is part of the explanation for how children acquire a verb vocabulary. Specifically, what remains to be demonstrated is (a) that the input children actually receive provides the information that syntactic bootstrapping requires and (b) that children use that information in learning conventional (i.e., not nonsense) verbs. The present study was designed to address the former issue.

For sentence structure to be a useful source of information about verb meaning in the way that the theory of syntactic bootstrapping describes, children's input must meet two requirements. The first is that categories of verbs with different meanings (e.g., motion vs. internal state) reliably appear in different frames (e.g., prepositional phrases vs. sentence complements) and different frames reliably distinguish categories of verbs. The second is that individual verbs appear in multiple frames. The reason for this second requirement is that there is no unique mapping between a single verb meaning and a single verb frame. Instead, the full power of syntactic information to constrain verb meaning is found in the set of frames in which a verb can appear. For example, the verb *see* can appear with directional PPs (e.g., "I can see all the way to the mountains"), which would suggest that it should be categorized as a verb of motion. Yet *see* differs from other motion verbs in that its motion is covert, nonphysical, and abstract (the above sentence means something like "My gaze goes all the way to the mountains"). This more cognitive part of the meaning of *see* is captured in that it can also appear with sentence complements (e.g., "I don't see what you are getting at"), as mental state verbs do. Thus, either frame reveals only one aspect of the meaning of *see*; the two of them together indicate that *see* involves both motion and mental states and thus is a verb of perception (Jackendoff, 1983, 1990; Landau & Gleitman, 1985).

Previous research on properties of child-directed speech has amply demonstrated that speech to children uses a small vocabulary and restricted sentence complexity compared with the language as it is used among adults (Snow & Ferguson, 1977). However, both requirements of the syntactic bootstrapping hypothesis depend on the input containing a variety of different syntactic structures. Therefore, it is possible that the simplified speech addressed to children does not provide the syntactic information that syntactic bootstrapping requires.

Recent research on child-directed speech that specifically investigated the potential support for syntactic bootstrapping provides some supportive evidence but leaves many questions unanswered. Lederer, Gleitman, and Gleitman (1995) found that verbs that clustered together semantically also tended to appear in the same syntactic frames in the mothers' speech (e.g., mental state verbs appeared with sentence complement frames). However, Lederer et al. did not investigate how often the verbs appeared in their "appropriate" frames or how often the frames appeared with the "appropriate" verbs, which is crucial to the potential usefulness of syntactic bootstrapping for young children. Rispoli (1995) examined the input to children by Japanese caregivers and found that only 17% of utterances containing transitive action verbs used the canonical syntactic frame. However, Rispoli did not directly compare the frames provided for transitive versus intransitive verbs. Such an analysis might show that, whereas transitive verbs do not always appear with a direct object, direct objects always appear with transitive verbs, and therefore the presence of a direct object would still be a reliable cue to the presence of a transitive verb. Landau and Gleitman (1985) examined the linguistic input to a blind child and found that over a period of 7 months the mother used the verbs *look* and *see* in differing syntactic frames sufficient to distinguish these verbs from their potential rivals (because *look* and *see* were verbs of haptic perception to this child) *hold, play, give,* and *put*. However, it is not clear whether this finding extends to the input given sighted children or to other verbs.

The purpose of the study that follows was to examine the syntactic bootstrapping hypothesis in terms of the evidence of the kind of input the child receives. This investigation asked the following: (a) Are the frames in the input reliable cues to the semantics of the verbs with which they appear? For example, do direct objects appear mostly with verbs that involve actor–patient relations, and do sentence complements appear mostly with mental or internal state verbs? and (b) Does the input present the verbs in multiple frames in profiles that could distinguish one verb from another?

To address these questions, we used Hoff-Ginsberg's (1991) database of mother–infant dyadic interactions in American English at two different times in development. This database is particularly suited to the analyses we planned, because the first session was scheduled to occur when the children were just beginning to combine words, which is also when they are beginning to use verbs regularly (Tomasello, 1992) and thus, by hypothesis, when the children should be particularly attuned to verb syntax.

Method

Sample

The participants were 57 mothers, who were videorecorded in their homes while engaged in naturalistic conversation with their 1.5- to 2.5-year-old children as described in Hoff-Ginsberg (1991). All of the participants were White, native speakers of American English. Twenty-four of the mothers were high school educated; 33 were college educated. The children were selected to be at the point in which they were just beginning to combine words at the time of the recorded visit. The children's mean length of utterance (MLU) in morphemes was 1.26 (SD = 0.11), and their mean age was 21.3 months (SD = 3.1).

Procedure

After at least one preliminary visit by a researcher, each mother–child dyad was videotaped at home in four settings: meal time, dressing, toy play, and book reading, with only brief interruptions between settings. Only utterances from the first three settings were analyzed for this study. Other family members were not present during the videotaping. Additional methodological detail is available in Hoff-Ginsberg (1991).

Transcription and Extraction

The videotapes of these interactions were transcribed by trained undergraduate research assistants following the conventions for the use of the Systematic Analysis of Language Transcripts (SALT) program (Miller & Chapman, 1985). The 57 mothers included in the present study were selected from a larger sample of 63 by excluding 6 mothers who produced the least amount of speech. The shortest transcript in the remaining set contained 393 utterances, and all other maternal transcripts were truncated to that length. For most of the mothers, the transcripts included the last 150 utterances produced during mealtime, the last 100 utterances produced during dressing, and the last 143 utterances produced during toy play. If a transcript had fewer than these numbers in any setting, more were retained from other settings to keep the total to a constant 393. (The 6 mothers who were excluded only produced an average of 200 utterances in total.) In summary, the transcripts were exactly matched in total length, based on three different interactive settings, with roughly equivalent portions of the total number of utterances from all settings for all participants.

We selected 25 common verbs as the focus of our investigation: *go, come, put, push, sit, take, see, want, pull, open, need, like, look, give, think, drop, fall, lay, move, lie, know, jump, run, hear,* and *listen.* These verbs vary in both their syntactic and semantic properties: For example, on the syntax side, some of the verbs are transitive (*take, put*), some appear with sentence complements (*think, know*), and some require prepositional phrases (*put*). On the semantics side, some verbs involve motion (*go, push*), some causation (*put, drop*), and some internal states (*want, need, look*). No single frame will unambiguously classify many of these verbs (e.g., *know* can appear either in a transitive frame ["I know her"] or with a sentence complement ["I know that it is raining"]). All utterances that contained any of the 25 target verbs were identified in the transcript using SALT and were extracted in their entirety for frequency tabulation and parsing.

Parsing

The maternal utterances were parsed into syntactic frames by two graduate students in linguistics at Yale University, using the conventions of X-bar syntax (Radford, 1988) with some adaptations (see later). One graduate student's primary function was to do the initial parsing, whereas the other's was to check a subset of the initial parses. Both students worked with Letitia R. Naigles in creating and refining the parsing scheme, details of which are given below.

Units. The purpose of the parsing scheme was to capture the different types of sentence frames in which the target verbs appeared in the maternal utterances. Because we were interested in the child's possible use of syntax in determining verb meaning, we restricted the units to grammatical ones such as noun phrase (NP), prepositional phrase (PP), sentence complement (S), and adverb (Adv) instead of semantic ones such as agent, action, and recipient. Combinations of these units constituted the set of frames. Because we were specifically interested in the aspect of the sentence frame most closely related to the verb, we only parsed the postverb elements of each utterance. The utterances were parsed at two levels of detail: narrow, data-driven frames and broad, theory-driven frames.

Narrow frame categorization. Our first categorization of the frames in which verbs were presented in maternal input was one that was bottom-up, designed to reflect as closely as possible the strings of syntactic units that young children might extract from the sound stream. Thus, for example, the utterance "She likes juice a lot" would be given the parsed frame *NP Adv*; the NP represents the noun phrase "juice" and the *Adv* represents the adverbial phrase "a lot." The utterance "Let's go to the store" yielded the parsed frame *PP,* which represents the prepositional phrase "to the store."

In three cases, our parsing scheme diverged from strict X-bar syntax because we were guided by assumptions of less rather than more syntactic sophistication in the child. In the first case, we included the nongrammatical category LOC (for *locative*) to describe words such as *home, outside,* and *here.* In the second case, we did not distinguish those postverbal units that are obligatory for the formation of grammatical sentences, such as the NP and PP for *put,* which are termed *arguments,* and those that are optional, which are termed *adjuncts*. For our 25 target verbs, adjuncts would include adverbs, temporal PPs, most locative PPs, and clauses following conjunctions such as *so* or *but*. Thus, the frame for "Let's see IF GRANNY'S HOME," where IF GRANNY'S HOME is an adjunct, was *S,* which was the same as the frame for "Do you know HOW TO DO IT?," where HOW TO DO IT is an argument. In the third case, we added narrow frames to capture the unique structure of *Wh-* (who, what, and which) questions and exclamations. In these utterances, the target verb is often utterance-final, yet the utterance contains NPs, PPs, and Ss that are usually considered to be part of the verb phrase. For example, the Wh- question "What do you want?" was given the frame "# (Wh-NP)," and the exclamation "Up you go!" was given the frame "# (P)." The full set of 45 narrow frames is given in Table 1.

Broad frame categorization. A major requirement for input to support verb learning via syntactic bootstrapping is that the verbs be presented in syntactic frames that are potentially informative for verb learning. Therefore, the uses of the 25 target verbs were also categorized into four broad syntactic frames, three of which have been hypothesized to be relevant for verb learning (Fisher et al., 1991; Fisher et al., 1994) and one of which served as a control. The theoretically derived frames were the following. (a) Transitive (NP), in which the target verb is immediately followed by an NP direct object (e.g., "You pushed THE BALL"); verbs in this frame are hypothesized to involve agent–patient relations. (b) Sentence (S), in which the target verb is followed by an S anywhere in the postverbal phrase (e.g., "I don't know IF YOU CAN DO THAT"); verbs in this frame are hypothesized to involve internal states. (c) Prepositional phrase (PP or P), in which the target verb is followed by a PP or P anywhere in the postverbal phrase (e.g., "Let Mommy put you INTO THE HIGH CHAIR NOW"); verbs in this frame are hypothesized to involve motion. Notice that the semantic predictions of these broad frames are conservative ones; in reality, each frame (given that we have dispensed with the argument–adjunct distinction) can appear with a wider range of verbs. Such conservatism works against our hypotheses, as we should be less likely to find that the frames reliably co-occur with their hypothesized category of verbs. Finally, as a control, we also looked at one syntactic frame type that has not been hypothesized to correlate with verb meaning, namely, the presence of an adverb (Adv) anywhere in the verb phrase (e.g., "What do you want NOW?").

Verb Categorization

To investigate how syntactic frames may be predictive for the meanings of particular verbs, we categorized the 25 target verbs in terms of their meanings in two ways along two independent dimensions, as proposed by various linguistic and psycholinguistic analyses. (The labels used for these semantic classes have been the topic of much discussion by both linguists and psychologists; however, few deny the existence of the categories themselves.) One semantic category (Dimension 1 in Table 2) divided the verbs according to their agent–patient relations. Group 1 verbs highlight both actors and patients, and so by hypothesis are more likely to be transitive, whereas Group 2 verbs involve only actors, and so are more likely to be intransitive. Group 3 verbs can involve both actors and patients, but one or the other of these roles can also be ignored, so that the verbs can appear either transitively or intransitively. A second semantic category (Dimension 2 in Table 2) divided the verbs according to whether they involved internal states

Table 1
Frames and Examples Used

Frame	Example
Verb final (= utterance final)	
#	Come!
# (Wh-NP)	What kind of juice do you want?
# (P)	Up you go!
# (LOC)	Here you go!
# (AdjP)	How pretty you look!
Particles (P) immediately follow the verb	
P LOC	Go around outside, go over here
P NP	Give up the box
P	Come out, go in, put in, run away
P Adv	Come out quickly
P [conj] S	Come out and look, it goes in where you put it
P PP	Go down to the basement
P (Wh-NP)	What are you looking at?
P NP [conj] S	Sit down this way until I tell you
Prepositional phrases (PP) immediately follow the verb	
PP	Go to the store
PP PP	Go to the store in the morning, sit in the chair like this
PP Adv	Go to the store today
PP LOC	Go with the dolly here
PP [conj] S	Go to the store and then we'll eat lunch
Noun phrases (NP) immediately follow the verb	
NP	Drop the ball, move the chair
NP PP	Push the box under the chair, open the door like this
NP LOC	Push the box here
NP P	Push the box around, take this apart
NP P PP	Push the box around like this
NP Adv	Push the button twice
NP NP	Give me the box
NP (Wh-NP)	Which box did you give her?
NP P Adv	Put it down right now
NP LOC S	Put it right there so it won't fall
NP P [conj] S	Put it away and go to sleep
NP PP [conj] S	Put the doll in the box and go to sleep
NP P LOC	Put it over there
NP (SVI)	Goes the bear, there goes the bear
NP [conj] S	Like it when you're happy
NP P (Wh-NP)	What did you put this in?
NP AdjP	Want you clean and tidy
NP Adv [conj] S	Let's put a big pile together then you can scoop them up
Sentences (S) immediately follow the verb	
S (Wh-NP)	Who do you think is going to the store?
S	Let's see if granny's home, I know that you like this
Locatives, adverbs, adjectives, sounds follow the verb	
Adv	Go slow, fall asleep, take forever, open wide
AdjP	You look pretty
LOC PP	You went there on an airplane
LOC Adv	No, we're not going outside right now
LOC [conj] S	You can't go outside if you don't put your pants on
LOC	Come home, go night-night, go potty
Sound	Go clang-clang

Note. Frames in parentheses indicate moved element, when frame-final, for example, S (Wh-NP). Frames in brackets indicate occasional element, when frame-internal, for example, NP [conj] S. Wh = *who, what,* and *which* questions; NP = noun phrase; P = particles; LOC = locative; Adj = adjective; conj = conjunction; S = sentence; PP = prepositional phrase; Adv = adverb; SVI = subject–verb inversion.

Table 2
Verb Categorization by Semantic Class

Dimension 1: Actor–patient relations				Dimension 2: Internal state vs. motion		
Group 1 (n = 8): Actor-and-patient	Group 2 (n = 10): Actor-only		Group 3 (n = 7): Actor-or-patient	Group 4 (n = 9): Internal state	Group 5 (n = 16): Physical motion	
Give	Come	Listen	Need	Think	Come	Push
Put	Sit	Lie	Drop	Know	Go	Put
Take	Go	Run	Hear	Need	Lay	Pull
Like	Think		Open	See	Move	Lie
Want	Fall		Move	Want	Sit	Run
Pull	Jump		See	Look	Open	Give
Push	Look		Know	Like	Take	Drop
Lay				Hear	Fall	Jump
				Listen		

(Group 4 verbs; by hypothesis, these are more likely to be followed by sentences) or motion (Group 5 verbs; by hypothesis, these are more likely to be followed by Ps or PPs). There was no hypothesized semantic group predicted by the adverb frame; therefore, we expected that the use of the adverb frame would cut across these verb categories fairly evenly.

Results

Mothers' Verb Uses

The transcripts for all 57 mothers combined yielded 4,863 tokens of these 25 verb types. Each verb was used with an average frequency of 194.52 (range = 1 [*listen*] to 1,116 [*go*]). Each verb was used at least once by at least 1 mother, and some verbs (*go, put,* and *want*) were used by all 57 mothers. The average number of verb tokens that mothers produced was 88.26 (SD = 17.67, range = 51–133); the average number of verb types was 14.56 (SD = 1.90, range = 11–19). The set of utterances containing these verbs constituted about 22% of the corpus of 22,401 maternal utterances; the other 78% of utterances either contained no verbs (36%) or contained other verbs (e.g., *do, say, eat:* 42%).

As discussed earlier, a total of 45 different narrow frames (see Table 1) was necessary to capture the diversity of syntactic frames in which these verbs appeared in maternal speech. Each frame appeared with an average of 5.67 different verbs (SD = 4.63, range = 1–20).

Do the Verbs Appear With the Appropriate Frames in Maternal Speech?

In this section, we investigate the extent to which the different types of verbs in the maternal corpus were used in the relevant (and irrelevant) syntactic frames. This investigation is more than routine, because for many of these verbs, use in the relevant syntactic frames is neither a grammatical nor a semantic necessity. That is, motion verbs do not have to appear with prepositional phrases; it is entirely proper to say "Run quickly!" Likewise, internal state verbs need not appear with sentence complements, for example, "See the doggie?" or "What are you thinking about?" However, for syntactic bootstrapping to be able to proceed, we would expect, for example, that internal state verbs should be followed by sentences more often than motion verbs are and that motion verbs should be followed by PPs more often than internal state verbs are. For this analysis, the frequencies with which each target verb appeared in each of the four broad frames were calculated, and then these frequencies were averaged within each semantic grouping of verbs. Only the results for the relevant frames for each semantic grouping are presented here; that is, verbs in the actor–patient grouping only differ syntactically with respect to their co-occurrence with the NP frame, and verbs in the motion–internal state grouping only differ syntactically with respect to their co-occurrence with the PP and S frames. Table 3 presents the average percentage of verb uses in the relevant frames (plus the Adv control frame) for each semantic grouping of verbs.

As predicted, Table 3 shows that the actor-and-patient (AAP) verbs appeared with direct objects the most, the actor-only (AO) verbs the least, and the actor-or-patient (AOP) verbs fell in between. Pairwise Mann–Whitney U tests between the AAP verbs and the AOP verbs, between the AO verbs and the AOP verbs, and between the AAP verbs and the AO verbs were performed. The AAP verbs appeared with direct objects significantly more often than the AOP verbs, $U(8, 7) = 3.0$, $p < .05$, and than the AO verbs, $U(10, 8) = 80$, $p < .01$. The AO verbs appeared with direct objects significantly less often than the AOP verbs, $U(10, 7) = 80$, $p < .01$. Thus, these three groups of verbs differed according to their frequency of use with NP frames in maternal speech. In contrast, the AAP, AO, and AOP verb groups did not differ according to their frequency of use with the Adv frame.

Also as predicted, Table 3 shows that internal state verbs were followed by sentences more often than motion verbs were; a Mann–Whitney U test found that this difference was significant, $U(9, 16) = 8.8$, $p < .01$. The complementary distribution also held: Motion verbs were followed by PPs or Ps more often than internal state verbs were, $U(16, 9) = 117$, $p < .01$. It is clear, then, that the S and PP or P frames successfully distinguished the internal state verbs from verbs of motion. Such observed differences are particularly compelling given that nonmotion verbs can be followed by some types of PPs (e.g., "I'll think ABOUT THAT"), and nonmental state verbs can be followed by some types of Ss (i.e., adjuncts, such as "Let's go to

Table 3
Mean Percentages and Standard Deviations of Verb Uses That Included These Frames

Dimension/frame	Verb group				
	AAP (n = 8)	AOP (n = 7)	AO (n = 10)	Motion (n = 16)	Internal state (n = 9)
Actor–patient					
Noun phrase					
M	86.84	45.34	0.80		
SD	12.71	21.65	1.37		
Adverb					
M	7.51	3.46	6.37		
SD	6.56	3.02	9.58		
Motion and internal state					
Sentence					
M				5.80	27.25
SD				4.69	25.71
Prepositional phrase or particle					
M				49.70	21.28
SD				24.39	32.98
Adverb					
M				7.71	2.75
SD				8.67	2.26

Note. AAP = actor-and-patient; AOP = actor-or-patient; AO = actor-only.

the store SO THAT YOU CAN GET YOUR CANDY"). What our results show is that even without distinguishing among the subtypes of PPs or Ss, the broad, theory-based syntactic distinctions of verbs with different meanings corresponded to the ways mothers actually used these verbs in child-directed speech. In contrast, and also as predicted, adverbs followed motion verbs and internal state verbs in roughly equal proportions; the Adv frame did not differentiate the two verb groups.

Do the Frames Cue the Appropriate Verbs in Maternal Speech?

A second requirement for input to yield the effects of syntactic bootstrapping is that the syntactic frames in maternal speech be reliable cues for particular verbs or verb classes. That is, as discussed in detail by Fernald and McRoberts (in press) in reference to another bootstrapping theory, it is not enough that particular verb classes be often followed by the appropriate syntactic frames, because the children who are to benefit from syntactic bootstrapping probably have not formed those verb classes yet. In fact, the syntactic frames are hypothesized to help them form those classes. Therefore, it is also critical to investigate whether particular syntactic frames most often appear with verbs in particular classes. For example, it is not enough that internal state verbs are followed by sentence frames more often than motion verbs are. This is because, if motion verbs happen to be more frequent in the sample under analysis (as they are in our corpus), then children may actually be hearing S frames equally often with motion verbs and internal state verbs. The critical question, then, is whether most utterances containing S frames have main verbs that involve internal states. If they do, then the sentence frame is a reliable cue, from the children's point of view, to the presence of an internal state verb.

For this analysis, we used the same broad frames and semantic categories developed for the prior analysis. Across all of the mothers, we totaled the number of verb-containing utterances that contained each frame and then calculated the percentage that also included each verb group. Thus, for example, we calculated what percentage of maternal utterances containing NP frames had an AAP verb, an AO verb, or an AOP verb. Because this analysis takes the child's point of view, all of the frames were considered important and potentially diagnostic of each semantic grouping of verbs; therefore, the results present the percentage of maternal utterances containing each verb type for every broad frame. Following Fernald and McRoberts (in press), we considered findings between 60% and 80% to be moderately reliable cues and those over 80% to be strongly reliable cues. The results are presented in Table 4.

As Table 4 shows, the NP frame is a strongly reliable cue to the presence of an actor-and-patient verb; in fully 85% of the utterances containing the NP frame, these direct objects followed an AAP verb. In contrast, neither the S frame nor the PP frame was a reliable positive cue to the actor–patient relation of the preceding verb. Utterances containing the PP or P frames appeared with AAP and AO verbs almost equally often, and in only half of the utterances containing the S frame did such a frame follow an AO verb. Contrary to our earlier prediction, the Adv frame was also a moderately reliable cue to the presence of an AAP verb.

Table 4 also shows that, in spite of there being more motion verbs than internal state verbs in our corpus, the S frame was a reliable cue to the presence of an internal state verb in the utterance. Thus, if the children exposed to this corpus conjectured, "If this utterance contains an S frame, then the main verb involves an internal state," they would be correct about two thirds of the time. Likewise, the PP or P frames were strongly reliable cues to the presence of a motion verb in the utterance. Table 4

Table 4
Percentage of Utterances Containing These Frames That Follow Verbs in These Classes

Dimension/verb group	Frame			
	NP	PP or P	S	Adv
Actor–patient				
Actor-and-patient	85.2	49.8	22.1	62.8
Actor-or-patient	13.4	3.2	26.6	6.5
Actor-only	1.4	46.9	51.2	30.6
Motion and internal state				
Internal state	38.2	15.2	67.0	17.6
Motion	61.7	84.7	33.0	82.3

Note. NP = noun phrase; PP = prepositional phrase; P = particles; S = sentence; Adv = adverb.

also shows that both the NP frame and Adv frame were reliable cues to the presence of a motion verb.

Are the Verbs Presented in Multiple Frames in Maternal Speech?

In this section, we investigate whether the maternal input presented our target verbs in multiple syntactic frames. Thus, we asked how often mothers both (a) used the same verbs more than once and (b) produced these multiply-used verbs in more than one frame. In our corpus, mothers used an average of 77% (*SD* = 11%, range = 54%–94%) of the verbs more than once in 393 utterances. We then examined the frames in which just the multiple-use verbs were produced. Considering just the four broad frames (NP, S, PP or P, Adv), we found that mothers produced an average of 56% (*SD* = 15%, range = 29%–92%) of these verbs in more than one frame. Considering all 45 narrow frames, we found that mothers produced an average of 79% (*SD* = 11%, range = 54%–100%) of the multiply-used verbs in more than one frame. Thus, over three quarters of the verbs are used multiple times, and one half to three quarters of these are used in multiple frames. Each mother used an average of 2.57 narrow frames per verb type produced (*SD* = 0.39, range = 1–12). Thus, it appears that one plausibility condition for the multiple frames tenet of syntactic bootstrapping has been met: Children do hear verbs presented in multiple syntactic frames.

Do the Verbs Appear in Unique Syntactic Profiles?

Table 5 presents the narrow frames used with each verb in the corpus; the number of broad frames used is also noted. As shown in the table, diversity of frame use ranges from 27 narrow (and 4 broad) frames used with *go* to only 1 frame used with *listen.* Every verb that was produced more than once in the corpus, however, was also used in more than one narrow frame and more than one broad frame. The average number of narrow frames in which an individual verb appeared was 10.56 (*SD* = 6.08, range = 1–28); for broad frames, this number was 3.32 (*SD* = 0.84). Moreover, close scrutiny of Table 5 indicates that across all 57 mothers, each verb has a unique profile of narrow frames used. (We realize, of course, that no child actually receives input from 57 mothers. The purpose of describing the entire corpus is to provide a general characterization of child-directed speech as prolegomenon for analyzing the speech of individual mothers and, ultimately, the verb learning of their children.) For example, *go* appeared with the frame PP LOC whereas *come* did not, and *come* appeared with the frame NP Adv whereas *go* did not. Likewise, *pull* but not *push* appeared with the frame P NP, whereas *push* but not *pull* appeared with the frame P PP. And *need* but not *like* appeared with the frame NP AdjP, whereas *like* but not *need* appeared with the frame Adv.

Even those verbs that were used less frequently could be distinguished by the types of narrow frames with which they were produced. For example, both *drop* and *move* were low-frequency verbs in this corpus (12 and 19 tokens, respectively). Both were used in similar numbers of narrow frames (five and six, respectively), and broad frames (three for both). However, the types of frames used were different for the two verbs: Although both verbs were used with Ps (hence, motion), with direct objects, and utterance-finally (hence, actor-or-patient), *drop* was also used with PPs and adverbs whereas *move* was used with LOCs and Ss. It is not obvious how these narrow frame differences might translate into meaning differences for the children; however, it is clearly the case that narrow frame differences have the potential to make some meaning-based distinctions among verbs, even when the verbs appear infrequently.

Finally, we investigated whether unique frame profiles could be obtained from the speech of 8 randomly selected mothers. The unique profiles of narrow frames for each verb that were observed for the corpus as a whole are seen again, by and large, for these individual mothers. For example, 1 mother used the frames P, PP, and LOC with *come;* no other verb was used by her in just these three frames. Likewise, another mother used the frames PP, PP PP, #, and S with *look,* and no other verb was used by her in just these four frames. For 3 of the mothers, each and every verb sampled had a unique profile of co-occurring narrow frames. For 3 other mothers, two verbs shared the same frame profiles. For the 7th mother, two verbs each appeared in only the NP frame, and two others only in the S frame. For the last mother, each of four pairs of verbs appeared in the same verb profile. Overall, then, these 8 mothers tended to distinguish the 25 verbs in unique syntactic ways (mean percentage of verbs used in unique frame profiles = 87%, range = 53%–100%). Furthermore, even when there was some overlap, it was never the case that more than two verbs shared a narrow frame profile. (The matrix of verbs by frames for each mother is available from Letitia R. Naigles.) In summary, it appears that a child who could take account of these narrow frame profiles would have a means of distinguishing each of the verbs produced.

Discussion

This study investigated the extent to which the linguistic input mothers provide their children could enable the children to use probabilistic syntactically based information in the process of verb learning, that is, syntactic bootstrapping. We have four findings. First, the input provides the necessary information for syntactic bootstrapping, in that the verbs are used in informative syntactic frames. For example, in maternal speech to chil-

Table 5
Narrow Frames in Which Target Verbs Were Used

Frame	Target												
	Come	Go	Fall	Drop	Move	Push	Put	Run	Jump	Give	Take	Open	Sit
#	+	+	+	+	+	+	+	+	+		+	+	+
# (Wh-NP)		+										+	
# (P)	+	+	+										
# (LOC)	+	+											
# (AdjP)		+											
P LOC	+	+											+
P NP	+	+					+			+	+	+	
P	+	+	+	+		+	+		+		+	+	+
P Adv	+	+					+						+
P [conj] S	+	+	+		+								+
P PP	+	+	+			+							+
P (Wh-NP)	+	+											
P NP [conj] S													+
PP	+	+	+			+	+	+					+
PP PP		+											+
PP Adv		+				+							+
PP LOC		+											
PP [conj] S		+	+										+
NP		+		+	+	+	+			+	+	+	+
NP PP	+			+		+	+			+	+	+	
NP LOC					+	+	+						
NP P					+	+	+				+	+	
NP P PP						+	+			+	+		
NP Adv	+					+	+			+	+		
NP NP							+			+	+		
NP (Wh-NP)										+			
NP P Adv						+	+				+		
NP LOC S							+						
NP P [conj] S					+	+	+				+	+	
NP PP [conj] S						+	+						
NP P LOC						+	+				+		+
NP (SVI)	+	+											
NP [conj] S	+					+	+				+		
NP P (Wh-NP)							+						
NP AdjP													
NP Adv [conj] S							+				+		
S (Wh-NP)		+											
S	+	+	+						+			+	
Adv	+	+	+	+		+		+			+	+	+
AdjP													
LOC PP	+	+											+
LOC Adv	+	+											
LOC [conj] S	+	+											+
LOC	+	+				+							+
Sound		+											
Total narrow frames	21	27	9	5	6	18	20	3	4	6	15	11	17
Total broad frames	4	4	3	3	3	4	4	2	2	3	4	4	4
Total frequency	198	1,122	97	12	19	179	807	9	21	113	208	57	178

Note. # = utterance final; Wh = *who, what,* and *which* questions; NP = noun phrase; P = particle; LOC = locative; Adv = adverb; conj = when frame-final, for example, S (Wh-NP). Frames in brackets indicate occasional element, when frame-internal, for example, NP [conj] S.

dren who were beginning to acquire a verb vocabulary, not only were motion verbs frequently followed by prepositional phrases (49% of utterances), but they were also followed by these elements more than twice as often as other, nonmotion verbs were (21% of utterances). Rispoli (1995) did not find as much syntactic information for the transitive–intransitive distinction he investigated in the input provided to Japanese learners, but he did not directly compare the frames provided for transitive versus intransitive verbs (AAP and AO verbs, in our terminology) as we did. In addition, his conclusions are limited by the small number of utterances he analyzed (fewer than 50 per caregiver). It is clear that a more extensive analysis of input in other languages, along the lines we have conducted here, is called for to investigate whether languages that allow phrasal ellipsis can enable syntactic bootstrapping.

Our second finding was the obverse of the first finding: Not

verb												
Lay	Lie	Pull	Look	See	Think	Like	Want	Hear	Know	Need	Listen	Types
		+	+	+	+	+	+		+	+		20
+		+		+	+	+	+	+	+	+		11
												3
												2
			+									2
			+									4
+		+										8
+			+				+					13
	+											4
+			+		+							6
			+									7
+			+									3
												1
+			+	+	+		+		+		+	15
			+									3
			+									4
			+									2
			+									3
+		+		+	+	+	+	+	+	+		18
+				+		+	+			+		12
				+			+					5
		+					+					7
		+										5
		+		+		+	+	+		+		10
						+				+		5
												1
		+					+					5
												1
										+		5
												2
		+		+								6
												2
		+		+		+	+			+		9
												1
							+			+		2
				+								3
												2
			+	+	+	+		+	+	+		11
	+	+		+	+	+						13
			+	+								2
												3
												2
												4
		+	+									6
				+								2
8	2	12	15	14	7	9	12	4	5	10	1	
3	2	4	3	4	4	4	4	3	3	4	1	
18	2	37	295	409	213	162	475	24	151	62	1	

conjunction; S = sentence; PP = prepositional phrase; Adj = adjective; SVI = subject–verb inversion. Frames in parentheses indicate moved element,

only do verbs appear in informative frames, but the frames also have the potential to cue the appropriate class of verbs. From the children's viewpoint, the first finding indicates that they can often confirm what they may already suspect; for example, *take* is a motion verb because it appears with prepositional phrases 46% of the time. The second finding is in fact more directly in support of syntactic bootstrapping. It demonstrates that the broad, theory-based frames provide reliable cues to various classes of verbs, in that they appear with verbs in these classes more than 60% of the time. Thus, with this input, children can conjecture that if they hear a verb with a prepositional phrase frame, then that verb is likely to be a motion verb.

These two findings also provide an empirical (as opposed to theoretical) rationale for why multiple syntactic frames (rather than single ones) may be necessary in order for children to use syntax as a clue to verb meaning. That is, the information from each individual syntactic frame in our data could only be used probabilistically, because (a) most verbs did not appear in their

"canonically informative" frame all of the time (even AAP verbs appeared without direct objects an average of 15% of the time), and (b) no frame cued the appropriate verb class 100% of the time (partly because we did not distinguish between arguments and adjuncts in our coding, 33% of utterances with the S frame included motion verbs as the main verb). Our third finding was that children's input meets the requirement that the target verbs be presented in multiple syntactic frames. On average, over three quarters of the verbs produced by the mothers during interaction with their children over the course of a morning appeared in more than one narrow syntactic frame, and over half appeared in more than one broad frame. This finding lends plausibility to the notion that children use multiple frames in verb learning, because the frames are indeed readily available for use and because closely spaced, syntactically varied maternal speech has already been found to contribute to children's syntactic development (Hoff-Ginsberg, 1985; Nelson, Carskaddon, & Bonvillian, 1973).

Our fourth finding was that the set of narrow frames with which a verb appeared (its frame profile) had the potential to distinguish that verb from all others in our sample. This held for both high- and low-frequency verbs. Furthermore, in the speech of 8 of our mothers whose data were examined individually, almost every verb (86%) could be distinguished from the others by its narrow frame profile.

Taken together, then, these four findings suggest that the input that mothers provide their verb-learning children meets two requirements of syntactic bootstrapping: The frames provide reliable cues to the verb classes, and multiple frames are both present and informative. Thus, syntactic bootstrapping as a procedure for verb acquisition is rendered more plausible for the child learner. Having argued this, it becomes important to consider how the syntactic bootstrapping of verb meaning fits into a full account of acquiring verb meanings and what implications syntactic bootstrapping has for an account of the acquisition of syntax.

With respect to verb acquisition, the claim that children use syntax to acquire verb meanings does not preclude their use of other sources of information, including the visual–spatial scene, individual lexical items, semantic biases, and pragmatic information. The probabilistic cues provided by syntax might work in conjunction with probabilistic semantic biases, such as focus on the result of the action (Behrend, 1990), and probabilistic pragmatic biases, such as focus on the impending action (Tomasello & Kruger, 1992). Recent theoretical and computational research has suggested that learners may be most sensitive to regularities that are revealed by converging probabilistic cues (Billman & Heit, 1988). It is likely that these converging cues are responsible for the child's low error rate even in earliest verb use: Scrutiny of the Appendix of Tomasello (1992), in which are listed practically all of one child's verb uses before the age of 24 months (approximately 1,250 utterances), revealed that only 20 uses (2%) were erroneous in referring to an incorrect action or relation.

With respect to how syntactic bootstrapping of verb meaning fits into an account of syntax acquisition, syntactic bootstrapping does require that the child know some syntax before using syntactic frames to acquire verb meanings. However, the theory does not preclude children using verb meaning (in addition to other sources of information, e.g., Gleitman & Wanner, 1984) to acquire syntax. That is, children may well use the correlations between verb meaning and verb syntax that we have identified in their input in both directions, such that verb and syntax acquisition build on each other throughout language development (see Bloom, 1994, for a similar suggestion).

On such an account, the process of language acquisition is not really a bootstrapping operation, in which one part of a system (the bootstrap) is grasped firmly to get the whole system. Perhaps a better metaphor is language acquisition as rock climbing—the child starts with a toehold somewhere and uses it to reach another toehold, and so on (see Shatz, 1987, for a related suggestion). Syntactic bootstrapping is a procedure whereby a toehold in syntax can be used to get to a new level in verb acquisition. It remains a task for future work to develop an integrated account of language acquisition, which will specify what paths up the rock are possible and also when you simply cannot get there from here.

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