Verbs of a Feather Flock Together: Semantic Information in the Structure of Maternal Speech

Anne Lederer
Henry Gleitman
Lila Gleitman
University of Pennsylvania

Linguistic theorizing about language acquisition has primarily focused on phonetic and syntactic issues. A much ignored stepchild of the research enterprise has been the topic of word meaning: How do children aged 5 or 6 years come to know 15,000 or so words such that they can utter and understand them? The major reason for this benign neglect among linguists is that word learning has traditionally been seen as a problem with no interesting internal structure, solved by the particularistic business of lining up each word length formative with its extralinguistic contexts. For instance, the sound "aard-vark" occurs most regularly in the presence of aardvarks, the sound "receive" in the presence of receiving, and so on, and so the child can associate each sound with its meaning—a putatively simple and transparent mapping procedure.

However, challenges to the sufficiency of this approach go back at least to Plato and were compellingly explicated by Quine (1960): Any real-world observation in principle can support a bewildering variety of descriptions. An observed rabbit is also an observed animal, furriness, temporal rabbit stage, and collection of undetached rabbit parts. A substantive psychological literature responding to this challenge has now appeared, concerning constraints on the child's representational (perceptual and conceptual) biases (Carey, 1978; Hall & Waxman, 1993; Keil, 1989; Landau, in press; Landau, Smith, & Jones, 1988; Markman, in press; Soja, Carey, & Spelke, 1991; and many other sources).

More relevant to the work we present here, constraints on the interpretation of a new word also derive from the child's emerging understanding of language design. To put this as baldly as possible, things tend to surface as nouns, properties as adjectives, and actions as verbs. Thus a child who hears a new word can be guided in its mapping by noticing the telltale markings of its lexical class (e.g., whether she hears "a gorp," "gorpish," or "gorping"; Brown, 1957; Grimshaw, 1981; Pinker, 1984). This view has been extended by showing that there are cues to word meanings within as well as across lexical classes. Particularly, potential cues to the meaning of a new verb reside in the subcategorization frames in which it occurs in caretaker speech (Fisher, Gleitman, & Gleitman, 1991; Fisher, Hall, Rakowitz, & Gleitman, 1994; Gleitman, 1990; Landau & Gleitman, 1985).

The present article contributes to this position by analyzing maternal verb use to young children. We begin with a brief sketch of how verb syntactic structure appears to covary with verb semantic similarity and discuss how this covariance may facilitate learning. We then present an analysis of form/meaning relations in the speech of mothers talking to their infants. This analysis shows that frame-range information that distinguishes among the mothers' verb meanings is available in the children's input at the time in life when they are just beginning to learn their first verbs.

SYNTACTIC CORRELATES OF VERB MEANINGS

Sentences are the surface expressions of underlying predicate–argument structure, with the verb expressing the specific predicate and the nominals expressing the arguments. The mapping from underlying to surface structure, though complex, generally preserves this relationship (as codified in the *projection principle*; Chomsky, 1981). For example, a unary relation such as *fall* is expressed with an intransitive (one-argument) sentence, and a binary relation such as *push* is expressed with a transitive (two-argument) sentence. More generally, verbs that describe motion caused by voluntary adjustments of the organism's musculature typically occur with null complements:

(1) John giggled/climbed/fell/sneezed.

If the motion is necessarily caused by an external agent, there usually will be an additional NP to represent that cause, as in:

(2) Mary pushed/hit/rotated/lifted John.

Verbs can also encode the path over which or the location or state in which the affected entity ends up, as in:

(3) John put the ball on the table/poured juice into the glass/sent the tigers into a frenzy.

In English, these properties are typically represented by a prepositional phrase that describes this path (Gruber, 1967; Jackendoff, 1978; Landau, in press; Talmy, 1985). Thus, not only the number but also the position and case marking of NPs is related to the sense of the verb. As another example of the relation between surface form and predicate–argument structure, verbs that describe aspects of perception and cognition characteristically accept clausal complements. Compare, for example:

(4) John explains/thinks that Frank caught a wolverine.
(5) John *sleeps/*puts that Frank caught a wolverine.[1]

The difference in acceptability between Examples 4 and 5 makes sense because the verbs of Example 4 express a relation between an actor (John) and an event (Frank catching wolverine) and clauses are the linguistic expressions of whole events (Vendler, 1972).

These samples do not even scratch the surface of verb lexical organization, of course. The regards in which the complementation privileges of verbs are semantically conditioned have been a traditional focus of investigation by linguists (e.g., Jespersen, 1927), and remain so (Dowty, 1979; Fillmore, 1968; Hoekstra, 1992; Jackendoff, 1990; Levin, 1993; Pinker, 1989; Talmy, 1975; among scores of important sources). Our question here concerns the ways that these form–meaning correspondences might be exploited by a language acquisition procedure.

CLAUSE STRUCTURE AND LEARNING

If the clause structures are projections from the semantics of verbs, then a child who has extracted a verb meaning from observing the contexts of its use can predict its structural privileges. This idea was developed and eloquently supported in the work of Grimshaw (1981) and that of Pinker and his collaborators (Gropen, Pinker, Hollander, & Goldberg, 1991; Pinker, 1984).

We concentrate here on a converse claim: The child who understands the semantic implications of syntactic environments can recover aspects of the meanings of unknown verbs (Bloom, in press; Landau & Gleitman, 1985; Naigles, 1990; Naigles, Gleitman, & Gleitman, 1993; Waxman, in press). For example, if one hears *John is gorping*, it is unlikely that *gorp* means 'hit' and more likely that it means 'sneeze.'

[1]"*" represents sentences judged to be ill formed or unacceptable in everyday speech.

The chief argument for supposing that learners exploit this information source has to do with the difficulty of identifying a verb's meaning from observation of its extralinguistic concomitants. A significant proportion of verb utterances, even to babies, are not about the here and now (Beckwith, Tinker, & Bloom, 1989). Even if the context in which a novel verb occurs is pertinent, more than one thing is usually happening such that there is no unique interpretive choice. For example, John may sneeze while he hits Bill. The distinction between the two verbs can in the long run be extracted by cross-situational observation (see Pinker, 1984), but attention to the structure is a handy alternate route and has promise for explaining how children so often derive the sense correctly from a single scene–sentence exposure. Moreover, attention to the syntactic structure and the placement of nominals is especially important for disentangling the many paired verbs that just about always occur under the same real-world circumstances (e.g., *give/receive, chase/flee*; Fisher et al., 1994). Finally, syntactic deduction appears to be a necessary component in identifying such verbs as *want* and *believe*, whose mental senses are evidently impossible to cull from observing scenes in the world, but whose syntactic properties (clausal complements) are especially revealing (for experimental evidence see Gillette, 1992).

Examination of these issues has led us to a structure-sensitive approach to verb learning, one that works in tandem with the meaning-to-form deductions as described by Grimshaw and Pinker. In our view, learners do not acquire verb meaning by pairing the new word, as an isolated formative, with its real-world contingencies. Rather, they perform a sentence-to-world pairing. The structure of the sentence narrows the interpretive options left open by scene inspection by exposing the argument-taking properties of the novel verb. This allows the learner to decide whether to focus on the hitting or the sneezing aspect of the scene in view, to zoom in on only certain aspects of the extralinguistic context. This focusing role of the syntax accomplished, the precise identification of the verb is derived by inspection of its environmental contingencies.

An extension of this position attempts to respond to the fact that the sentence-to-world pairing procedure still seems too weak, even when amplified by cross-situational observation. This is because too many verbs share a surface environment and are used in situations that can easily be misleading. For example, the most frequent environment in maternal speech for both *want* and *eat* is a simple transitive: "Did you eat the cookie?" "Do you want a cookie?" Observers are biased to identify a novel verb as related in meaning to *eat* if shown a relevant scene and informed of this structure (Gillette, 1992). Even if shown further scenes in which *eat* cannot be the correct construal (e.g., a scene in which the mother offers a drum to the child), subjects guess another physical action term (e.g., *take* or *get*) and are mulishly resistant to conjecturing a mental term such as *want*. However, if they hear a disambiguating syntactic structure (and even if the content words in this structure have been converted to nonsense, e.g., "Did vany GORP to blitso the ribenflak?"), they guess a mental verb. The suggestion is that although single sentence–scene observations are often uninformative, a small and manageable set of sentence–scene observations allows convergence on the correct interpretation.

It is this suggested procedure whose data basis is examined in the analysis now presented. We ask whether the set of syntactic environments offered by mothers to the learning child inevitably places the learner in the correct semantic neighborhood—whether verbs whose range of syntactic privileges is similar share components of their interpretations. If this is not so in the child's real learning environment, it follows that syntactic range can play no part in the learning procedure. But if it *is* so, then the approach gains plausibility.

AN ANALYSIS OF MATERNAL SYNTACTIC USAGE

This analysis describes the verb use of native English-speaking mothers talking to their young children.

Subjects

The subjects were 8 middle-class English-speaking mothers. Their children ranged in age from 12 months, 5 days to 25 months, 3 days (mean = 20 months, 9 days). The mean length of the children's utterances (MLU) ranged from 1.2 to 1.6 (mean = 1.5). Their vocabulary consisted predominantly of simple nouns and social words (e.g., *bye-bye*), with few or no verbs, but they were just at the point where verb learning begins in earnest.

The Corpus

Maternal speech was videotaped during hour-long sessions in a laboratory playroom. The mothers were instructed to play with their children, using the toys that were scattered around the room. An experimenter who minimally interacted with the mother and child was also present.

Materials, Coding, and Preliminary Analysis

The videotapes were transcribed, and all transcribed utterances containing a verb were extracted from each mother's speech sample (copulas and auxiliaries were excluded). The frequency of each verb in each mother's speech was calculated. We retained for further analysis all verbs that appeared (across mothers) at least 32 times and had been uttered by at least half of the mothers. This yielded an average of four uses of each verb by each mother. A total of 24 verbs satisfied these criteria, yielding a total of 2,183 utterances for the analysis. The 24 verbs are listed, in descending order of frequency, in Table 10.1.

Syntactic Analysis

The verbs were analyzed according to the structures in which they appeared in the maternal speech, as follows.

Number and Type of Complement. The subcategorization frames were extracted in an orthodox fashion. For example, the sentences

1. The elephant is sleeping.
2. Bonnie saw the dog.

TABLE 10.1
Verbs Included in Analysis of Maternal Usage

Verb	*Frequency Across Mothers*	*Number of Mothers Who Used Verb*
go	179	8
see	171	8
come	166	8
say	157	8
do	145	8
put	142	8
get	137	8
look	136	8
want	118	8
have	110	8
know	94	8
like	78	8
think	67	8
take	65	8
find	53	6
play	49	7
push	49	5
show	45	7
sit	41	6
catch	39	4
call	37	7
make	36	6
eat	36	7
pull	33	6

3. Johnnie put the book on the table.
4. I know you like ice cream.
5. Do you want to pick up the blocks?
6. Look how I do it!

were coded as

1. V
2. V NP
3. V NP PP
4. V S_t
5. V S_u
6. V S_{fr}[2]

Intonation. We used the maternal intonation in certain cases to decide whether the utterance was a question or imperative. This was done because verbs vary as to whether they license imperatives (compare, e.g., "Accuse him of treason!" and *"Suspect him of treason!"). Although this distinction is not one of subcategorization as usually conceived, it is a distinction of syntactic environment that is informative of the semantics of activity versus state. Intonational features were also used to distinguish quotation contexts such as, "So she goes/says, 'Don't touch that!' "[3]

Progressive Versus Simple Past/Present. Only some verbs are comfortable in the progressive form as a consequence of the active/stative distinction in their semantics (compare "I am thinking of you" and *"I am believing in you").

Matrices of Verb Use

A verb by frame matrix for each mother was constructed. Across all mothers, the 24 verbs appeared in 71 structural environments, as these were defined in the preceding section. A verb was said to occur in a particular environment in the usage of a mother if it appeared in that environment at least twice.

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[2]S_t = tensed sentence complement, S_u = untensed sentence complement, S_{fr} = sentence complement introduced by a free relative.

[3]This last decision is admittedly problematical. We have no hard evidence that the direct quotation intonation differs from that of tensed sentence complements when these are introduced without a complementizer (e.g., "He thinks John is coming"), for we performed no physical analysis of the stimuli. Skeptical readers should simply excise this variable from their interpretations of the result tables with the consequence that the set of distinctions shown here to be cued by frame-overlap becomes somewhat smaller.

Differences in frequency of appearance in these environments were ignored: For the purpose of this analysis, the question is only whether each verb does or does not appear in each environment. The outcome, then, is a 71 $\times$ 24 matrix for each mother.

A sample portion of such a matrix is shown in Table 10.2. To read this table, notice that *know* and *get* are distinct in Environment 1 (appearance with null complements, i.e., bare intransitives), share Environment 2 (appearance with NP complements), and so forth. It is these overlaps and nonoverlaps that are the information sources for a hypothetical structure-sensitive verb learning procedure.

Collapsing the Matrices: Similarities Across Mothers

Before examining these matrices, we first assessed how similar the mothers were in their verb use. This is because the idea that structural privileges play a causal role in learning would be falsified if it turned out that different mothers used the verbs in different structural environments while the children all acquired the same meanings for them.

Using Hildebrand's *del* statistic (see later discussion for an explanation of Hildebrand's *del*), we assessed the strength of the relation in syntactic usage between all possible pairs of mothers in the sample of 8 mothers. There were 28 such pairs. The finding was that the similarity between each pair was significant ($p < .0001$): All mothers used about the same structural environments for each of the 28 verbs. This obtained similarity across mothers justifies pooling all the maternal data into a single matrix, henceforth called the *supermatrix*.

The Structural Environments of Maternal Verb Use

No 2 of the 24 verbs appeared in all and only the same structural environments in any of the 8 mothers' usage or in the supermatrix. This result is not very interesting as it stands, for it is likely that in a larger sample some

TABLE 10.2
Sample Matrix of Maternal Usage

	Verbs			
Frames	*know*	*get*	*put*	*come*
V NP PP		+	+	
V NP	+	+		
V	+			+
V S	+			

Note. A + indicates that the verbs appeared with the frame on that row.

verbs would completely overlap in their syntactic ranges. The question of interest is whether degree of frame overlap is predictive of semantic similarity over the verb set as a whole: Do verbs whose meanings are alike tend to occur in the same syntactic environments? Preliminary experimental evidence exists to support such a conclusion about the organization of the English verb lexicon (Fisher et al., 1991); moreover, closely related findings have been obtained in a replication for Hebrew (Geyer, Gleitman, & Gleitman, 1993). Our question is whether mothers come close to this same picture.

To find out required three steps. First, we performed an analysis to discover which of the 24 verbs overlap syntactically (i.e., share certain frames). Second, we performed an experiment and an analysis to discover which of these verbs are semantically similar. Third, we asked if the syntactic and semantic similarity spaces, so derived, are essentially the same: Is the semantic similarity space predictable from the syntactic similarity space? If so, then the potential usefulness of frame ranges for narrowing the hypothesis space for verb learning receives support.

Discovery of the Syntactic Clusters

To compute a syntactic similarity score for each verb pair, we used a measure of the number of structural environments on which the two verbs matched syntactically in the supermatrix. Such an analysis is by no means simple to carry out realistically, for matching on certain structural criteria may be more informative for a learning procedure than matching on others. For example, literally thousands of verbs accept the simple transitive environment of (2); thus, this environment does little to differentiate among verbs. In contrast, a very small subset of verbs appears with sentence complements, as in (4); thus, appearance in this latter structure can be very informative.

To mirror this difference in the information value of individual structures, we weighted the matches between verbs by the frequency of the structures themselves across verbs in the set of 24. That is, the similarity score for each pair of verbs was equal to the sum of the weighted structural matches; each match was weighted by the frequency with which the frame occurs in the set of verbs as a whole. Using this weighted measure, we constructed a syntactic similarity matrix for the 24 verbs.

This new matrix was subjected to an overlapping cluster analysis to extract regularities in the syntactic organization of the supermatrix. Cluster analysis refers to a class of methods for picking out natural "clumps" in similarity data (Gordon, 1981). The algorithm located overlapping clusters, in which each verb in the set could be a member of more than one cluster. This overlapping cluster analysis is the only realistic one for the kind of data we are considering, for verbs participate in several cross-cutting subcategorizations. Thus, for example, verbs like *think* and *explain* match in accepting certain sentence complement environments (e.g., John thinks/explains that

Claire is clever) that *give* does not accept (e.g., *John gives that Claire is clever). In a cross-cutting categorization, *give* and *explain* but not *think* share a three-NP environment (e.g., John gives/explains/*thinks a book to Joe). Thus the patterning is complex, and it is the complexity itself that is revealing: Because *think* and *explain* involve mental events, they share the sentence complement environment, but because *explain* and *give* involve transfer (in this case, transfer of a book), they share the ditransitive environment. Thus, *explain* describes mental transfer, that is, communication (Zwicky, 1971). The cluster analysis is designed to draw out these cross-cutting patterns. Its results with the supermatrix yield seven overlapping clusters, as shown in Table 10.3.

In essence, these clusters are the groups of syntactically congruent verbs that fall out of the syntactic overlap in the mothers' speech. The clusters provide a good representation of the syntactic similarity data, yielding an overall r^2 of .70. Notice in Table 10.3 that each cluster is well described by overlap on a single frame. For example, *come, go,* and *look* (cluster 1) all accept intransitive environments with a prepositional frame: John comes into the room, John looks at the table. Both *want* and *like* accept untensed sentence complements (cluster 3, e.g., I want him to go to the store; I'd like him to whistle).

Informally, there is a whiff of semantic substance to these patterns of verb use. Cluster 1 verbs seem to pertain to physical or perceptual motion with directional paths (Gruber, 1967; Jackendoff, 1983) and cluster 3 verbs

TABLE 10.3
Syntactic Clusters

Cluster	*Frame Variable*	*Example Frame*	*Verbs*	*Cumulative r^2*
1	V PP[a]	John goes to the store.	*come, go, look*	.26
2	V S_r[b], V S_{fr}[c]	John knows who he likes. John sees how to do it.	*know, see*	.39
3	V S_u[d]	John likes to go to the store.	*like, want*	.44
4	V NP PP[e]	John put the ball on the table.	*call, get, pull, push, put, take*	.58
5	V PA[f]	Sit up! Get on!	*come, get, go, sit*	.64
6	V S_c[g]	I know that you are happy.	*know, think*	.67
7	V DI[h]	I said, "Get off the couch!"	*call, do, go, say*	.70

[a]V PP = A verb taking a prepositional phrase.
[b]V S_r = A verb taking a sentence complement introduced by a relative pronoun.
[c]V S_{fr} = A verb taking a sentence complement introduced by a free relative (e.g., *how, if*).
[d]V S_u = A verb taking an untensed sentence complement.
[e]V NP PP = A verb taking a noun phrase and a prepositional phrase.
[f]V PA = A verb taking a particle (e.g., *on, up*).
[g]V S_c = A verb taking a sentence complement introduced by a complementizer (e.g., *that*).
[h]V DI = A verb taking a whole sentence that is quoted to its right.

pertain to states of desire (Vendler, 1972). But we do not really want to make claims about the semantic correlates of these syntactic patterns based on such informal intuitions. Rather, we develop an experimental approach to this question in the next section.

Here, it is important to note only that the patterns of maternal syntactic usage, even in the space of a one-hour play period, yield a number of rather refined groupings. This opens the door for hypothetical learners disposed by nature to exploit these patterns as a basis for semantic inferences. Similarly, they provide the exemplars for hypothetical learners who, having made semantic inferences from extralinguistic observation, are disposed to project the structures onto semantically similar verbs that they may subsequently encounter (Bowerman, 1982).

Experimental Discovery of the Semantic Space

We consider the semantic space for the same set of verbs. The semantic space of interest is the one that characterizes the adult lexicon. This is the target toward which the learners are aiming. The first question, then, is how the 24 verbs under consideration are semantically related to one another as judged by adult speakers. Once we have determined the semantic groupings, we ask how these are related to the syntactic groupings derived in the analysis just presented.

Method. Subjects were presented with all possible triads of the set of 24 verbs without syntactic context and were asked to choose the semantic outlier in each triad. The final measure of the semantic relatedness of any two verbs was the percentage of times they stick together (i.e., are not chosen as outliers) in the triad judgment in the context of all third verbs with which they are presented. The idea is that if no third verb (in the set) is semantically closer to either of these verbs than the two are to each other, then the two must be very close in their meaning. This method was previously used by Fisher et al. (1991) and Geyer et al. (1993) to study form–meaning linkages in the adult lexicon.

Subjects. The subjects were 28 native English speakers, students at the University of Pennsylvania.

Stimuli. The stimuli were all possible triads of the 24 verbs in Table 10.1.

Procedure. Subjects was shown three verbs on a CRT screen. They were asked to choose the one verb of these three that was "the least similar in meaning" to the other two. They began with 10 practice trials consisting of verbs not in the experimental set. Because it would border on torture to ask a single subject to respond to all of the 2,024 possible sets of the 24 verbs taken three at a time, we broke down the set of triads into smaller groups. Each subject was presented with 150 triads, selected randomly from the complete set of 2,024. Thus, it takes 14 people to make a "composite subject." Two such composite subjects (28 individual subjects) were run.

Scoring. The subjects gave judgments of the degree of similarity of each verb pair in the context of all other (22) verbs in the set. We computed an index of similarity of the verbs by counting the number of times that any pair of verbs stuck together in the contexts of other verbs (following Fisher et al., 1991). Because there were 24 verbs, each pair appeared in the context of 22 other verbs. Therefore the similarity score for any given pair could range from 0 to 22.

Reliability. We tested to be sure that there was a high level of reliability between the two composite subjects, obtaining a Spearman's rho of .78. This level of concordance is significant at the .001 level as calculated by Hubert's conservative estimate and is similar to the level of concordance achieved by prior studies using this method. This result justified pooling the responses of the two groups.

Extracting the Semantic Organization of the Verb Set. We subjected the semantic similarity matrix obtained to the same overlapping cluster analysis used to construct the syntactic similarity matrix. Just as in the syntactic analysis, using a cutoff of r^2 of .70 we obtained seven semantic clusters. These are shown in Table 10.4. These clusters represent the structure implicit in our subjects' judgment of the meaning overlap of the verbs in our set. In Table 10.4, we have (rather clumsily) provided these clusters with semantic labels, but we should emphasize that these labels are rather arbitrary and are presented in the table only for their gross value as pointers to (whatever) may be the real semantic identifiers of these groups. It should not be surprising to find that this semantic labeling is rough. After all, the semantic organization of verbs across the mental lexicon is unlikely to be expressible with a small set of (other) words or phrases of English. In fact, that the method of triads does not force us to provide a label for these semantic generalizations is one of its major strengths. In the usual methods of linguists in this regard, the logically distinct problems of discovering a semantic correlate of a syntactic property and labeling that semantic correlate are conflated. In contrast, the semantic groupings we obtained derived from the subjects' own judgments as they fell out of the cluster analysis shown in Table 10.4, and the syntactic groupings fell out of an independent cluster analysis of maternal usage (see Table 10.3).

TABLE 10.4
Semantic Clusters

Cluster	*Semantic Label*	*Verbs*	*Cumulative r^2*
1	Cognition/Perception	*find, have, know, like, look, see, think, want*	.10
2	Active	*call, catch, come, do, eat, find, get, go, make, play, pull, push, put, show, sit, take*	.45
3	Discovery/Communication	*call, find, look, say, see, show*	.53
4	Mental	*do, get, know, look, make, say, see, show, think*	.56
5	Transfer	*catch, find, get, pull, push, put, take*	.64
6	Cognition	*know, like, think, want*	.68
7	Possession	*get, have, take, want*	.70

Two properties of the clusters in Table 10.4 should be noted particularly. The first is that many verbs whose overall meanings differ exceedingly appear in each cluster. All the same, the clusters represent some shared aspect of construal that subjects (implicitly) perceived and that contributed to the judgmental patterns. Although *push* and *take* are quite different, they have a likeness that we have labeled *active transfer* (cluster 5). Second, the overwhelming majority of verbs appear in more than one cluster. For instance, *want* shows up both as a verb of cognition (cluster 6) and as a verb of possession (cluster 7). In some ways, then, the outcomes of this analysis appear to have some fidelity to the relations among the verb meanings, and the clusters appear to represent components of these overall meanings rather well.

Analysis for Semantic/Syntactic Relations

At this point, we have extracted two similarity spaces. The first is a syntactic space derived from overlap in the frame-range privileges for verbs exhibited in maternal speech (Table 10.3). The second is a semantic space derived from adult choices of semantic outliers in the triad task (Table 10.4). We next wanted to examine how these two spaces overlap. That is, we wanted to know whether the syntactic groupings of the verbs are predictive of the semantic groupings of the verbs.

Comparing the Two Matrices. To accomplish this comparison, we set up a new matrix, shown as Table 10.5. In Table 10.5, the column headings are the seven syntactic clusters obtained from the syntactic analysis (see

TABLE 10.5
Matrix of the Relation Between Syntax and Semantics in Maternal Usage

	Syntactic Clusters with Frames						
Semantic Clusters with Semantic Labels	*Cluster 1: V PP (3)*[a]	*Cluster 2: $V\ S_r$ (2)*	*Cluster 3: $V\ S_u$ (2)*	*Cluster 4: V NP PP (6)*	*Cluster 5: V PA (4)*	*Cluster 6: $V\ S_c$ (2)*	*Cluster 7: V DI (4)*
Cluster 1: Cognition/Perception	1[b]	2	2	0	0	2	0
Cluster 2: Active	2	0	0	6	4	0	3
Cluster 3: Discovery/Communication	1	1	0	1	0	0	2
Cluster 4: Mental	0	2	0	1	0	0	2
Cluster 5: Transfer	0	0	0	5	1	0	0
Cluster 6: Cognition	0	1	2	1	0	2	0
Cluster 7: Possession	0	0	1	2	1	0	0

[a]Numbers in parentheses indicate total number of verbs in each syntactic cluster.

[b]Numbers in each cell indicate the number of verbs in the syntactic cluster in the column that appeared in the semantic cluster intersecting at that row. In other words, each cell indicates the overlap in membership of the verbs in each syntactic and semantic cluster.

Table 10.3). The row headings are the seven semantic clusters obtained from the semantic analysis (see Table 10.4). Each cell indicates the number of verbs common to the semantic cluster and the syntactic cluster that intersect at the cell. For example, the verbs in syntactic cluster 1 (V PP) are *come, go,* and *look.* The verbs in semantic cluster 1 (Cognition/Perception) are *find, have, know, like, look, see, think,* and *want.* Because *look* is the only verb common to both clusters, the entry in this cell (row 1 and column 1) is 1. As another example, the verbs in syntactic cluster 4 (V NP PP) are *call, get, pull, push, put,* and *take.* The verbs in semantic cluster 2 (Active) are *call, catch, come, do, eat, find, get, go, make, play, pull, push, put, show, sit,* and *take.* Because all six verbs in syntactic cluster 4 appear in semantic cluster 2, the entry in the appropriate cell (row 4 and column 2) is 6. In sum, each cell in the matrix consists of the number of verbs that appear in both the semantic cluster and the syntactic cluster that make up that group.

If there were no relation between the syntactic and semantic clusters, then the numbers in each cell of Table 10.5 would be distributed randomly. Inspection suggests that the distribution is nonrandom, for some cells contain large numbers and others are empty. The question was how to determine whether this pattern could be obtained by chance.

The usual statistic for assessing the relationship between two categorical variables is chi square. However, as Table 10.5 shows, there are many zero cells in the matrix, and many verbs that appeared in one category also appeared in another. As a result, using the chi square was ruled out. We therefore turned to another test, Hildebrand's *del* statistic, which was designed to handle data of just this sort (Hildebrand, Laing, & Rosenthal, 1977; Hildebrand, 1986). The *del* assesses the strength of the relation between two categorical variables by comparing the number of errors generated by the actual data to the number of errors generated by a randomized replication of the data. However, its application requires some principle that allows us to predict an expected set of cell frequencies that can then be compared to the number that was actually obtained.[4]

Predicting the Relation Between the Categories. To develop a principle on the basis of which we could predict the overlap between the syntactic and semantic categories, we made two assumptions. First, following Jackendoff (1983) and Pinker (1984), we assumed that the child believes verb construals are drawn from some large but limited set of overarching conceptual categories: physical motions, including their paths and goals;

[4]In assessing the overlap in the syntactic usage among the mothers, we had run into similar problems with chi square. The number of zero and small cells was just too great to warrant that test. Therefore, as described earlier, we used the *del* also to assess the similarity in syntactic usage among the mothers in the study.

mental acts and states; and so on. For the 24 maternal verbs, these categories are represented by the clusters of Table 10.4—the semantic space extracted from adult judgments. Second, based on a body of findings from linguists and developmental psychologists, we assumed that the argument-taking properties of verbs are reflected systematically in the surface structures that they accept and that these patterns are—correcting for architectural distinctions—much the same across languages of the world (Chomsky, 1981; Grimshaw, 1981; Jackendoff, 1978). These assumptions granted, a learning procedure that derives aspects of a new verb's meaning from inspection of its syntactic correlates can operate on the following principle:

> If a verb belongs to syntactic group X and assigns some semantic property p to this syntactic group, all verbs subsequently observed to fall into syntactic group X will be assigned property p. Verbs of a feather flock together.

Notice that this hypothetical learning principle is attentive to positive information only. It draws inferences about semantics only from structures in which a new verb is observed to occur. No inferences are based on the absence of some structure in the database for a new verb. After all, further structures may be observed at some later time; their current absence may be of little significance.

Applying this principle to predict from syntax to semantics without error, it would have to be the case that every time a member of a syntactic cluster is a member of a semantic cluster, all other members of that same syntactic cluster are also members of that same semantic cluster. We can clarify this generalization by inspection of cluster 6 in Table 10.5, in which just this relationship obtains. *Know* and *think* are the verbs that comprise syntactic cluster 6, and for every semantic cluster of which *know* is a member, *think* is also a member.

If this type of relation between the syntactic and semantic clusters held across the board, then we could predict from syntax to the semantic classification of Table 10.4 without error. Inspection of Table 10.5 shows that this perfect relation does not hold, except for syntactic cluster 6. Thus, it is clear that in trying to predict from syntax to the semantic groups, our hypothetical learner would make some errors. However, it is also clear from inspection of the matrix that the proportion of errors would be small.

The learning principle provides the prediction rule that allows us to compare the number of errors generated given the actual cell frequencies in the matrix to the number of errors generated given the expected cell frequencies. The *del* is the percent error reduction from the random replication to the actual obtained data.

Using this statistic, we determined whether the number of errors the child will make (given the obtained syntactic and semantic spaces of Tables 10.3 and 10.4) is significantly smaller than the number of errors he or she would make if only a chance relation existed between the two spaces. That is, if the relation between the two spaces is not at chance, we can assess how much power the structural facts about the verbs in our corpus give the child for predicting the semantic organization of these verbs.

We found that the syntactic formats have considerable predictive power. According to the *del* statistic, children would make 49% fewer errors than expected by chance in organizing the verb set semantically if they had knowledge of the syntactic organization of the verb set. This finding is significant at the .0001 level. The magnitude and reliability of this obtained relationship is quite remarkable considering the indirectness of the triad procedure we have used to extract the semantic organization of the 24 verbs.

Summary of the Findings

Our results show that caregivers provide rich syntactic information about common verbs for their very young children. Each verb had a distinctive distribution of subcategorization frames for each mother. The distribution was highly similar for all mothers, even in these small (one-hour long) corpora. Our question was how well the distributional structure of the corpora mapped onto the target semantic space, as assessed independently from the triad procedure. The answer was that overlap in frame range was a powerful predictor of the semantic organization of the maternal verb set. Thus, the database provided to children embodies the form–meaning correlations that are required for the syntactically sensitive verb learning procedure first suggested by Landau and Gleitman (1985).

DISCUSSION AND CONCLUSIONS

The form–meaning linkages in maternal—and all—speech appear to serve language learning in more than one way. The first, suggested in a seminal discussion from Grimshaw (1981), is to reduce two learning tasks to one: To the extent that a verb's meaning can be acquired from observing its contexts of use, aspects of its structural privileges follow, namely those that are consequences of the argument structure implied by the verb semantics. This position (elaborated significantly by Pinker, 1984) assumes the universality of these mappings and assigns them as a feature of the innate apparatus that children bring into the language learning task.[5] The evidence supporting such a view is strong. Linguists' investigations of the languages of the world over the past several decades demonstrate that, correcting for the architecture of specific languages, the same mappings characterize lexical structure in diverse languages. Moreover, Bowerman's (1982) analyses of child errors of subcategorization are best understood as corrections for local quirks in these mappings in the target language. Additionally, the study of manual communication systems spontaneously developed by deaf children of hearing parents (Feldman, Goldin-Meadow, & Gleitman, 1978; Goldin-Meadow & Feldman, 1977) shows that, without a model, children can project these same mappings (e.g., one noun phrase for sentences with *sleep*, two for sentences with *hit*, and three for sentences with *give*). The clause structure, in the relevant regards, can be bootstrapped from knowledge of the verb semantics.

We have argued here and elsewhere that built-in knowledge of the form–meaning linkages can also be used in the reverse direction: A verb's appearance in some particular structure constrains the logic it can be expressing. As we remarked in the introduction to this chapter, such constraints on the search space for verb meaning are particularly useful where observation provides little evidence. It is hard to parse scenes to come up with interpretations like "want" and "believe," but clausal complements can suggest that the speaker had mental acts and states in mind. More generally, the argument structure of a new verb can be bootstrapped from its linguistic context, putting the learner in a narrow neighborhood concerning its precise meaning. Given such constraints from structure on the semantic search space, learning the verb from its contexts of use becomes feasible. The present analysis provided one demonstration required by such a claim: The maternal corpus embodies the form–meaning linkages quite regularly.

This is not the place to review the form-to-meaning feature of verb learning in detail. However, a few words are in order about the nature of the hypothesis (see Fisher et al., 1994, for a full discussion). It goes without saying that one cannot learn the meaning of a verb (or any word) "from" its syntactic contexts. The subcategorization frames provide only information relevant to the argument structure, and that information is shared across many verbs. For example, *roll, bounce, slide,* and many other verbs are verbs of motion that can express a path as well as the agent causing the motion. These similarities in their meanings lead to identity in their argument structures and thus frame ranges (e.g., John rolls/bounces the ball down the hill; The ball rolls/bounces down the hill). But these verbs are not synony-

[5]It is presumed by most investigators that not all complementation is semantically conditioned, that there are some semantically arbitrary facts about subcategorization in natural languages at every point in their history. Because this is likely so, the deductions from form to meaning and from meaning to form can succeed only probabilistically. The necessarily errorful nature of these deductions is best revealed in the work of Bowerman (1982) on child errors in subcategorization, such as, "He falled me down."

mous, for they differ in the type of motion described. Acquiring these distinctions of manner requires observation of the verbs' distinctive contexts of use. At best, then, the frame range for these verbs can reveal that these are motion/path verbs of some kind. Our position is that this partial information is a requirement for inspecting the extralinguistic world relevantly. For instance, thoughts, desires, purposes, and so forth are aspects of the real world that may be present during the utterance of *bounce*. As we have shown elsewhere, this complexity in the environment renders both adult and child subjects helpless to identify the meaning of a novel verb from scene information alone. However, they correctly conjecture the right meaning when they receive scenes paired with structures. Successful identification of a new verb requires a sentence-to-world pairing rather than a word-to-world pairing.

Our position is not that there are verb classes associated with different ranges of subcategorization frames as a consequence of their semantics. Rather, verbs have meanings, and sentence frames have semantic implications. Whether a verb appears in a particular frame is a matter of the compatibility of its meaning with the argument structure implied by the frame. Thus, given the meaning of *dance* it is unlikely to occur in a transitive structure, but this verb in this structure is perhaps not ungrammatical or even uninterpretable as the verb class position would have it. After all, one can say "Gepetto danced Pinocchio." What evidently happens here is that the sentence takes on the interpretation implied by the verb sense and the frame implication taken together. That is, if *dance* occurs in a transitive structure, then the motion (though ordinarily voluntary) was caused by an external agent. This is plausible when the dancer lacks volition, as a puppet.

This position implies that any verb can occur in any structure. In essence, the child need not learn the subcategorization facts about any verb, for there are no such facts, only relative likelihoods that verbs with certain meanings will appear in certain structures. Hearing "John gorps that Mary is hungry" raises the likelihood that *gorp* means "think" and lowers the likelihood that it means "eat." It is such compatibility relations that yield the usage picture laid out in Table 10.5 and help the child decide which verb has which meaning.

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