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On the Semantic Content of Subcategorization Frames

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This paper investigates relations between the meanings of verbs and the syntactic structures in which they appear. This investigation is motivated by the enigmas as to how children discover verb meanings. Well-known problems with unconstrained induction of word meanings from observation of world circumstances suggest that additional constraints or sources of information are required. If there exist strong and reliable parallels between the structural and semantic properties of verbs, then an additional source of information about verb meanings is reliably present in each verb's linguistic context. Five experiments are presented which investigate the following hypothesis regarding the scope of these relations: The closer any two verbs in their semantic structure, the greater the overlap should be in their licensed syntactic structures. To investigate this hypothesis, data of two kinds were collected from different groups of subjects: (a) One group of subjects was asked to judge the semantic relatedness of verbs by selecting the semantic outlier in triads presented to them. (b) A second group of subjects was asked to judge the grammaticality of these same verbs in a large range of syntactic environments. These two types of data were then compared to assess the degree of correspondence in the two partitionings (syntactic and semantic) of the verb set. The findings, overall, support the view that the syntax of verbs is a quite regular, although complex, projection from their semantics. In conclusion, we discuss the kinds of features that are formally marked in syntactic structure and relate these to the problem of verb–vocabulary acquisition in young children. © 1991 Academic Press, Inc.

> . . . if you invent a verb, say *greem,* which refers to an intended act of communication by speech and describes the physical characteristics of the act (say a loud, hoarse, quality), then you know that . . . it will be possible to greem (i.e., to speak loudly and hoarsely), to greem for someone to get you a glass of water, to greem to your sister about the price of doughnuts, to greem "Ecch" at your enemies, to have your greem frighten the baby, to greem to me that my examples are absurd, and to give a greem when you see the explanation. (A. Zwicky, 1971, p. 232)

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The question we address in this paper is a recurring one in the study of language: How are the structures of sentences related to the propositions they encode? Specifically, to what extent is it true that the semantic content of a verb is marked by the structure of sentences in which that verb appears? It is obvious that there are strong relationships of some kind here. After all, sentences are the linguistic devices for representing propositional thought, so the verbs that participate in describing very different kinds of propositions should, and do, appear in correspondingly different sentential formats. To take a simple example, the different number of noun phrases required by the verbs *laugh, smack,* and *put,* in the sentences

(1) *Arnold laughs.*
(2) *Arnold smacks Gloria.*
(3) *Gloria puts Arnold in his place.*

is clearly no arbitrary choice, but rather is semantically determined—by how many participant entities, locations, etc., the predicate implicates. And as Zwicky points out in the quoted passage above, fixing the meaning for a verb seems to allow prediction of many of its surface properties; that is to say, verbs that are related in meaning share aspects of their clausal syntax.

However, despite many such promising examples of syntactic/semantic linkages, the predictions from meaning to surface syntactic form appear complex at best, nonexistent at worst. Semantically close verbs will sometimes have divergent syntax:

(4) *John substituted a horse for a cow.*
replaced a cow with a horse.[1]

and semantically disparate verbs will often share syntactic environments; for example, the range of verb meanings expressible by simple transitive clauses is enormous, including

(5) *John escapes my memory.*
remembers my escape.
sings Yankee Doodle Dandy.
sees an analyst weekly.

The relevant question raised by (4)–(5) is whether they demonstrate that surface structures are, in detail, quite independent of the facts about semantic structure or whether, instead, they imply more subtle and various, but still real, relations between these levels of description.

Opinions on this general topic vary widely. At one extreme is the view

[1] This example is adapted from Grimshaw (1983), but see Landau and Gleitman (1985) for a suggestion that *substitute* and *replace* have a meaning difference that corresponds to this syntactic distinction.

that there is virtually no syntax of clauses that is independent of the semantics—that the surface structure is a completely regular, although complex, projection from the meaning of the verb; and at the other extreme is the view that, owing to countervailing nonsemantic constraints on language structure and accidents of language history, there is little prediction possible from the meaning of a verb to the surface structures licensed for its use. Although few are willing to man the barricades at either of these extremes, the range of current belief in between is very wide (for the classic early treatments of these issues, see Gruber, 1965; Fillmore, 1968; Anderson, 1971; and Jackendoff, 1972; and for a compendium of recent views, Wilkins, 1988).

In the present paper, we will introduce some new procedures for investigating the scope and reliability of semantic/syntactic relations. Essentially, the experimental procedures are more formal versions of traditional linguistic elicitation procedures. The resolving power of these experimental tools and the statistical analyses to which the results are submitted are assessed in the first two experiments presented, by applying these techniques to relevant syntactic/semantic generalizations previously induced by traditional linguistic methods. Thereafter we will present experiments that begin to show how results achieved by our procedures can enter into the linguistic debate on the structure of the verb lexicon.

More generally, though the investigations reported here directly concern the predictive power of surface clause structures for adult verb semantics, their underlying motivation has to do with children's discovery of the verb meanings in their native tongue. Elsewhere, we have argued that the child's extralinguistic (observational) context, taken alone, is too impoverished and unconstrained to account for acquisition of the verb meanings; and in response to this insufficiency we have proposed that young learners recruit the semantically relevant surface structures as a primary source of evidence concerning these meanings (for discussion and experimental evidence, see Landau & Gleitman, 1985; Gleitman, in press; Naigles, in press; Fisher, Hall, Rakowitz, & Gleitman, forthcoming).[2]

The scope of such a claim is strictly limited in two ways, which are studied in this paper. First, the child can use syntactic evidence for acquiring verb meanings only to the extent that the semantic/syntactic map-

[2] We want to emphasize that it is *surface structures* in particular whose semantic regularity will be of use to the child learner, and therefore whose properties concern us in the current work. We have argued elsewhere that, based on physical properties of the wave form, the child can extract a rudimentary surface parse of sentences heard (Gleitman and

pings are pervasive and regular, and more or less the same across languages. Therefore we want to understand the degree to which surface structure is a regular projection from lexical semantics. In this regard, the aims of this work are coincident with those of linguists studying lexical organization. Second, and for reasons that are intimately related to the logical problem of verb–vocabulary acquisition, we will ask about the *kinds* of semantic information that are predicted by the range of structures licensed for verbs (and, symmetrically, the kinds of semantic information that do *not* seem to be formally marked by the syntax), and about the transparency of these mappings. For after all, if the child can neither predict *what semantic information can be found in the syntax* nor *how that information will be linguistically encoded,* then the mere fact that there are syntactic/semantic regularities cannot be expected to aid in the acquisition process.

In a final discussion, based partly on these experimental results and partly on our and others' prior results, we will offer beginning generalizations in these regards: We will suggest that semantic information that is (a) domain general, (b) closed to observation, and (c) related to the argument-taking properties of the verbs is quite regularly encoded in surface structure. And we will conclude that these properties are encoded into the syntax because, for success in deducing the verb meanings, the child learner requires that this be so.

Before describing the experiments themselves, we want to sketch the kinds of semantic/syntactic correlations that we have in mind and that have been considered in the linguistic literature.

Relations between Verb Meaning and Clause Structure

A rock-bottom feature of language design is that particular verbs differ in the naturalness of their occurrence in particular grammatical constructions. For example, it is natural to say

(6) *John put a book on the table.*

but not so natural to say

(7) **John laughed a book on the table.*[3]

Laugh does not seem to permit a post-verbal NP (here, *a book*). That is, *put* occurs in structures like

(6′) NP V NP PP,

Wanner, 1982, 1985). These, along with scene observations, form the inductive basis for learning—the primary linguistic data for constructing knowledge of the native tongue. The question now raised is how much semantic information can, in principle, be extracted from the clause structure (more strictly, from the sister-nodes immediately dominated by VP).

[3] An asterisk (*) denotes a sentence which is judged to be ungrammatical. A question mark (?) denotes a sentence which is awkward, or for which grammaticality judgments differ

while *laugh* occurs in structures like

(7′) NP V.

Thus, the two verbs are associated with different complements, *put* accepting the complement *NP PP* and *laugh* accepting a null complement. Following orthodox linguistic terminology, we say that (6′) and (7′) are *subcategorization frames* (SubCat frames) and that *laugh* is associated with SubCat frame (7′), while *put* is associated with SubCat frame (6′), as shown by the data of (7) and (6).[4]

Semantic Correlates of Subcategorization Frames

Our question is the degree to which semantic generalizations accord with these distinctions of SubCat privileges for verbs. For the cases just exemplified, the number of NP's required for grammaticality appears to correspond to the number of semantic-relational elements (or *theta roles*) necessary to spell out the participants in the events described by the verb.[5] For example, the notion *putting* requires an entity who does the putting, a thing that is put, and a location into which it is put. Correspondingly, each such entity is required to appear as a NP in well-formed sentences containing *put*. Thus

(8) *John put poison in the cup.*

is predicted to be a grammatical sentence for it renders all and only these thematic roles (or *arguments*). Our claim is that the child should expect this regular mapping of verb logic onto NP's in the clause; moreover, that

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substantially across informants. To describe linguistic categories, we use the abbreviations N (noun), V (verb), P (preposition), and NP (noun phrase), VP (verb phrase), and PP (prepositional phrase).

[4] For present purposes, we have rendered the SubCat frames without bracketing information. But it should be understood that the subcategorization information for a verb includes only phrases within the VP, that is, complements of the verb. Of course almost any sentence can, in addition, include prepositional phrases that are not within VP and that do not subcategorize the verb set. For example, *put* and *laugh* and indeed just about all verbs will accept temporal or locative PP's (*John put his car in the garage/laughed/in Paris in the morning*). It is not always easy to make this distinction, in practice. As we shall discuss, this is one reason why the subjects in the experiments that we report were asked to provide scaled (rather than absolute) judgments of the relations between verbs and SubCat frames.

[5] In a recent version of generative grammar (Government and Binding theory; Chomsky, 1981), this relationship is stated as a general principle of language design: Every NP in a sentence must receive one and only one thematic role (the *theta-criterion*). Moreover, a related principle (the *projection principle*) states that the theta criterion will hold at every level of a derivation; in particular, that argument structure is preserved on the surface clause structures. Those linguists who accept these principles obviously have subscribed to a version of the view that lexical semantics determine the core structure of the clause (for discussion and argumentation pro and con see Fillmore, 1968; Bresnan, 1979; Williams, 1981; Jeffries and Willis, 1984; Cullicover, 1988; Ladusaw and Dowty, 1988).

in a sense that can be made precise this mapping is "cognitively transparent" (Jackendoff, 1978; Jackendoff & Landau, in press). In Jackendoff's words:

> . . . In order to lighten the language learner's load further, it seems promising to seek a theory of semantics (that is, of conceptualization) in which the projection rules [the mapping rules for semantics onto syntax] are relatively simple, for then the child can draw relatively straightforward connections between the language he hears and his conception of the world. The methodological assumptions for such a theory would be that syntactic simplicity ideally corresponds to conceptual simplicity; grammatical parallelisms may be clues to conceptual parallelisms; apparent grammatical constraints may reflect conceptual constraints. (1978, p. 203)

In fact, there is intriguing evidence for such a position, as regards the one-to-one mapping of thematic roles onto NP positions that we have been discussing: Deaf toddlers who cannot learn the language around them because of their deafness and who are not exposed to a conventional sign language (because their hearing parents do not know one) invent an iconic communication system that has just this property; for example, they associate one NP with their sign for *sleep,* two with *hit,* and three with *give* (Feldman, Goldin-Meadow, & Gleitman, 1978).

Not only the roles, but also their structural positions and type appear to be semantically determined for the *put* example that we are considering: The agent (*John*) appears as subject, the thing moved (*poison*) appears as direct object, and the location (*cup*) appears as indirect object, marked by a locative preposition. On the other hand,

(9) **John put poison.*

(10) **John put in the cup.*

(11) **John put poison in the cup the table.*

are ruled out because they contain too few or too many NP's to fill the argument positions.

(12) **Poison put in John the cup.*

wrongly positions these NP's in the surface structure; and

(13) **John put poison the cup.*

omits the required preposition for the indirect object.

In contrast to the case of *put, laugh* logically requires only its experiencer—the one who laughs—and hence can occur in clauses with a single NP:

(14) *John laughs.*

Further argument roles appear optionally with this verb, although never in the direct object position:

(15) *John laughs at fate.*

(16) **John laughs fate.*

If these examples are representative of the lexicon as a whole, the number and positioning of NP's in the clause reflect the logic of propositions in which verbs can figure. (We temporarily leave aside homonyms, quirks, provisos, and complications, as suggested by *John laughed the proposal off the table*. But we will return to these matters.) Thus the correlations between verb meanings and sentence structure are no accident in the design of a language. Rather, they exist simply because, other things being equal, a sentence making reference to a particular type of event or state of affairs will naturally allow the speaker to mention the necessary participants and to differentiate their roles in some systematic way (Dowty, 1986).

A number of such distinctions in the SubCat privileges of verbs have been examined in the linguistic literature and hypothesized to be reflections of semantic distinctions. Here are a few further examples, chosen because they represent the starting point for the experimental investigations we will present.

1. *Motion* verbs such as *put, walk,* and *give* allow or require prepositional phrases (PP's) which encode the sources, paths, and goals of objects moving through space (Gruber, 1965; Jackendoff, 1983, 1987; Talmy, 1975).

2. Verbs of *spatial perception* and of *cognition* characteristically allow sentential complements (SComp's) that describe the events perceived or the propositions cognized, while verbs that describe the physical motion of bodies in space usually do not occur with SComps (compare *John saw/believed that Mary was coming* with **John put/*gave that Mary was coming;* Vendler, 1972).

3. Verbs that describe *acts* are more natural in progressive and imperative structures than verbs that describe *states* (compare *John is accusing Mary of treason* and *Accuse Mary of treason*! with **John is suspecting Mary of treason* and **Suspect Mary of treason*!). (Lakoff, 1966, as cited in Dowty, 1975; Vendler, 1967)

4. Verbs that describe *symmetrical* relationships are natural in plural intransitive (*John and Mary met*) structures and unnatural in singular intransitive structures (**John met*) (Gleitman, 1965; Gleitman, Gleitman, Miller, & Ostrin, forthcoming).

5. Verbs that describe (externally caused) *transfer*, or *change of possessor,* of an object from place to place (or from person to person) fit naturally into sentences with three NP arguments (3-NP), while others do not. (Compare *John moved his belongings to Texas, John turned Mary into a bat, *Bill went Mary to the party;* Jackendoff, 1978; Pinker, 1987.)

A Componential Approach to Semantic Correlates

It is important to notice that almost all verbs appear grammatically in several SubCat frames. For instance, *close* appears in the structures

(17) NP V NP (*Evelyn closed the door.*)
(18) NP V (*The door closed.*)

The sense of the *verb* stays the same in these sentences, but even so the meanings of the two *sentences* differ in accordance with this distinction in form: (18) tells what happened to the door, but (17) expresses the *causal agent* in this affair as well, necessitating an additional NP (*Evelyn*) (Fillmore, 1968; Anderson, 1977; Carlson and Tanenhaus, 1988).

Speaking more generally, it is possible to suppose that SubCat frames encode certain abstract *components* or *elements* of sentence meaning. As an example (in fact, an example that we will partly revise later in discussion), consider the notion transfer (or change of possessor), which seems to be encoded just when sentences have three NP constituents within the clause, as

(19) *John gives a book to Mary.*
(20) *John tells a story to Mary.*

That *give* and *tell* are natural in such 3-NP structures is a consequence of the fact that transfer is a conceptualization that fits naturally with the overall meanings of these verbs: In (19), the *book* is going from *John*'s to *Mary*'s hands, and in (20) the *story* is going from *John*'s to *Mary*'s mind. In contrast, transfer fits less well with the overall meaning of such verbs as *have* and *think* for the verb concepts in these cases have to do with events within a single hand or mind; consequently a third NP is superfluous:

(21) **John has a book to Mary.*
(22) **John thinks a book to Mary.*

Now consider a distinction between *mental* (or cognitive/perceptual) and *physical* acts. SubCat frames with sentential complements are associated with verbs describing mental events, states, or acts. So since *tell* but not *give* is a mental act, the former is more natural than the latter in SubCat frames with sentential complements; compare:

(23) **John gives Mary that Bill is a CIA spy.*
(24) *John tells Mary that Bill is a CIA spy.*

In sum, certain abstract semantic elements are carried on the clause structure, rather than (or in addition to) as item-specific information in the lexical entries of verbs. These semantically relevant clause structures will be chosen for utterance only to the extent that they fit with the overall meanings of the verb items.

It follows from these claims that the SubCat frames, if their semantic values are known, can convey important semantic information to the child learner concerning the meanings of specific verbs. For the examples just given, the child may deduce that *give* encodes some concept consistent with transfer (since it will be heard to occur in SubCat frames underlying sentences like (19)) and that *tell* encodes some concept consistent with mental transfer (since it occurs in frames underlying both (19) and (24)). Thus the overlaps among verbs in the clause structures they accept can provide a partial semantic partitioning of the verb set for the learner.

Where Syntax and Semantics Diverge

So far we have drawn quite a rosy picture of semantic/syntactic relations. If this picture is true in detail and adequate in scope—that is, if the syntactic/semantic correlations are perfect and exhaustive over the range of meanings—this points the way toward a relatively straightforward acquisition procedure in the relevant regards. The child could draw inferences from observing the contingencies of use for a verb, thus deriving its meaning, and then project its structure from the meaning (Grimshaw, 1981; Pinker, 1984); but also the child could draw inferences from observing the structural privileges licensed for a verb (as revealed by the usage of caretakers) to derive its meaning (Gleitman, in press).

However, there are severe difficulties in bringing such a position to ground. One problem is that there are influences on clause structure that are not semantic; another is that if any and all conceptual categories are mapped onto the syntax, the learner will be faced with a wild proliferation of conjectures in trying to decipher these mappings.

Nonsemantic influences on clause structure. Certain constraints on language structure are at odds with the desideratum that it straightforwardly encodes the propositional logic. Some of these have to do with the overall syntactic and even phonological/prosodic architecture of particular languages, and some have to do with the morphosyntactic history of particular items. These often yield exceptional encoding of the propositional logic. To sketch this general problem, let us reconsider the question of whether the number of NP's in the clause uniformly maps one-to-one from the number of thematic roles.

Consider the verb *rain*. Notionally, it seems to require no arguments at all, yet it appears in sentences with a NP:

(25) *It's raining.*

There is no "who" who does the raining, and indeed the subject of *rain* is just a meaningless dummy (an *expletive,* in linguistic parlance). It is there just because in English (although not in all languages), an overt subject is required in the main clause. Thus, the general architecture of a particular language may have the effect that for some verbs there are one too many NP's in the clause than accord with the verb semantics.

The reverse situation occurs as well, owing to what Gruber (1965) described as the *incorporation* of arguments into the verb.[6] This often

[6] We do not claim that Gruber's (1965) account of these irregular mappings as "incorporations" is a broadly explanatory one. Basically, Gruber's commentary presup-

happens for so-called denominal verbs (verbs made from nouns) because their nominal morphology provides one of the conceptual arguments within the verb itself. For example, *buttering* involves someone (an agent) covering something (the goal of the motion) with something else (*butter*, the theme of the motion). Yet the theme does not typically emerge as a surface NP since it is already established as part of the meaning of the verb:

(26) *Edith buttered her toast (*with butter/?with margarine).*

The result is that *butter* has one too few surface arguments, from the point of view of a structural scheme that assigns a NP to each participant implied by the verb logic. For related reasons, occasionally the type of a NP will be nonstandard with respect to the way a language typically realizes certain semantic roles. An example is *exit*, from Latin and Old French *ex-* (*out of, from*) and *ire* (*go*). In the source language, a prepositioned morphological element (*ex-*) was a device used to mark the path of motion, just as in English paths are typically marked by prepositions (Jackendoff, 1978, 1983), as in

(27) John Barrymore went *off the stage.*

As residue of this linguistic history, *exit* in modern English can accept an exceptional syntax for encoding directed motion through space:

(28) John Barrymore exited *the stage.*

For these and related reasons, at any real stage of a language there are bound to be irregularities in the mapping between semantics and clause structures.

The enormity of conceptual space. There is no end of categories known and constructable that language can convey. Obviously, many such categories are mapped onto single lexical items while others are handled combinatorially, e.g., we would not expect there to be a morphologically simple word meaning "John runs" or "rich enough to send a four-horse chariot to the Olympics every 4 years." Whatever these limits on the notional constraints of the lexicon, however, it is rather amazing to see how much nuance is encoded into the monomorphemic verb vocabulary.

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poses a semantic/syntactic architecture that conforms to a version of the theta criterion and projection principle (Chomsky, 1981) such that, as we have described, the thematic roles are mapped regularly onto nominal phrases in the clause. "Incorporation" is essentially a name for observed violations of this and related principles, and a descriptive scheme for verb entries that acknowledges the possibility of violations. The conditions for these violations are what need a more general account. As we now mention briefly, phonological (Grimshaw, 1985), syntactic (Chomsky, 1986), and historical generalizations have been offered as sources of these violations, but to our knowledge no general explanatory account is available. What is clear is that such violations exist and affect the suasion of a learning procedure that is sensitive to the theta criterion.

In fact, this subtlety is one of the factors that makes language learning appear to be impossible. One example we have mentioned: the "stuff" that participates in the action or event may be incorporated into the verb's meaning, as in *butter, paint,* or *spit*. But there is much more, e.g., the mood of the speaker (*rage, fulminate*); his intended effect on the listener (*lull, cajole, persuade*); the sense organ involved in the act (*look, listen*); manner of speaking (*whisper, simper,* or for that matter, *greem*); manner of dissolution of the affected object (*crumble, shatter, tear*); rate, manner, and trajectory of motion (*race, hop, bounce*); change of coloration (*whiten, brown, flush, pale*); size (*grow, shrink*) or shape (*bend, squash*); degree of certainty (*think* vs *know*); forcefulness (*order, urge, request*); and so forth, on and on.

Few of these categorial distinctions are regularly mapped onto the structure of clauses; this is why the clause structures could provide only a very partial semantic partitioning of the verbs. In later discussion, we shall offer some preliminary conjectures about why languages make the choices they do for the properties to be displayed across the clause structure rather than packaged within the lexical item. But for present purposes it is sufficient to notice that inspection of the syntax can reveal only a subset of the components of a verb meaning to the learning child just because only a subset of them is there. Unless that learner has some rather refined expectations about the likely mappings between meaning and form, a deductive procedure that makes use of these mappings is simply out of the question.

Methodological Considerations in Semantics

We have just reviewed some regularities in the mapping from the semantics of the verbs onto their syntax. We know from prior work (Gleitman, in press, for a general statement) that these regularities are recruited by young children as a significant aid to discovering the meanings of the verbs. But as we also mentioned, these mappings are not wholly uniform and are nowhere near exhaustive. Just as regular mappings can aid the learner, so irregular and nontransparent linkages make trouble for an acquisition procedure that attempts to exploit these relations. It therefore becomes an interesting question just how stable and refined these relations are in the target language to which the learner is exposed, and just what the regularities consist of. How can this organization be investigated?

Explorations of the semantic organization of the verbal lexicon have proceeded in a number of ways. An obvious first choice of method is simply to trust our semantic intuitions, generating features of meaning by contemplating the various senses of verbs. The main problem with this approach is the enormous amount of disagreement that these proposed decompositions generate. For example, much ink has been spilled on the question of whether *kill* is a simple conflation of the features *cause* and *die* (see Lakoff, 1965; Fodor, 1970, for arguments pro and con). Such intuitions are notoriously unreliable. One reason may be that the success of these introspective methods depends on the commentator's ability to notice and label potential elements of meaning, some of which are far more elusive than others. Problems such as these have induced some to give up on the very idea of semantic decomposition (Fodor, Garrett, Walker, & Parkes, 1980; Armstrong, Gleitman, & Gleitman, 1983).

The work of Jackendoff, Talmy, and other linguists we have cited represents a considerable step up in this regard. Jackendoff's position, which we embrace, is that the rules linking syntax to semantics are bound to be reasonably direct—bound, that is, by the requirements of language acquisition. Assuming the validity of this general position, linguists in this tradition now examine the lexicon for grammatical parallelism among verbs on the supposition that there will be a semantic/conceptual generalization related to, hence explaining, that parallelism. Thus, by using the observable surface syntax as evidence for semantic components, it becomes possible to characterize the semantic side of the mapping by reference to an external criterion of its reality—the syntax itself. The working hypothesis that similarities of syntax reflect similarities in meaning will then provide a method for exploring the lexicon.

Even so, there are some difficulties in using this kind of linguistic analysis as the basis (or at least, as the sole basis) for reconstructing the mental lexicon. Again, only those semantic generalizations that can be readily labeled by the investigator are likely to be discerned. It may well be that there are semantic abstractions which, while correlated with the syntax, are not so easy to puzzle out and name. Even worse, disagreements over labels for semantic features can get in the way of deciding whether those features are marked in the syntax. That is, *isolating* semantic regularities that map onto syntax and *labeling* those regularities are separate problems. These two steps are confounded in the method proposed by Jackendoff since the only way to characterize an element of meaning is by giving it a name. Any counter-example that comes up could be an exception either to the syntax/meaning regularity itself, or to a faulty label.

In order to address these problems separately, we need to find a way to look at links between syntax and semantics without being committed to a label in advance. For the same reasons, it is desirable to have some reasonably objective way to assess what counter-examples imply about the underlying organization of the lexicon as a whole. What should be concluded from these offending instances, when they are found? For example, should the findings about *rain, butter,* and *exit* be taken to defeat the position that thematic roles map one-to-one onto surface positions in the clause (that is, that this is not a principle of language design) or only as evidence that this relationship is imperfect (that is, influenced by its interaction with other factors)? For the latter conclusion to be defended by more than arm-waving, it is necessary to have a method that extracts the regularities from the complex structure in which they may be embedded.

Summarizing, the idea that the structural and semantic partitionings of the lexicon are identical fails, to some unknown degree, in both directions, *but all the same the structural/semantic links may determine significant aspects of the lexicon as a whole*. This is the sense in which an imperfect but overall pattern can be interesting—as the reflection of one of several effects on the final organization of the lexicon. Viewed this way, the existence of counter-examples makes sense, but implies that the search for semantic/syntactic linkages can profitably be submitted to statistical test. In fact, statistical procedures are expressly designed for just this kind of problem: to detect the influence of factors that are embedded in a complex structure.

In the present work, which acknowledges the probabilistic nature of these mappings, we therefore resort to statistical investigative procedures. By such means, we can extract general design principles in the verb lexicon without presupposing their scope, nature, or labeling. It should be reemphasized, however, that we have been heavily influenced and guided as to where to look first by the results already achieved by various linguists whom we have cited.

Our specific approach is to induce (different) subjects to classify sets of verbs *both* syntactically and semantically. The overlaps in these independent classifications are then assessed by a regression analysis. In essence, this procedure provides an objective way to assess counter-examples (which always exist) to any proposed syntactic/semantic relation. Using this procedure, the generality and scope of semantic/syntactic correlations in the lexicon can be investigated quite systematically, essentially by manipulating the verb choices submitted to experimental test. Finally, the procedure will extract the correlational patterns whether or not we (or any investigator) can provide them with semantic labels such as transfer or cause.

Experimental Prospectus

We will attempt to make three main points in the experiments and analyses which follow: (a) the *range* of SubCat frames accepted by verbs permits a partial, but important, semantic partitioning of the verb set; (b) this semantic/syntactic partitioning is significant psychologically as well as linguistically; and (c) this partitioning can be extracted from ordinary speakers in an orderly and essentially mechanical fashion.

Our hypothesis is that there are refined correspondences between *sets* of SubCat frames and verb construals. If this is true, then the closer the perceived meaning of two verbs, the greater the overlap there should be between the SubCat frames licensed for them. The more disparate the verbs' meanings, the less their syntactic behavior should overlap.

We present five studies which investigate this hypothesis. In each of these, different groups of subjects give semantic or syntactic judgments for a set of verbs, and then the relationships between these two types of judgment are compared.

Experiment 1 is a first assessment of the resolving power of the method itself: Does it have the potential for exploring the mapping between syntactic structure and meaning? For this reason, this experiment examines gross aspects of the mapping that have been uncovered previously by others using traditional linguistic methodology, particularly the five classes of syntactic frames described earlier: those with PP, with SComp, with 3-NP arguments, in imperative or progressive or pseudo-cleft form (IPP), and in intransitive form with conjoined subjects (ICon). Experiment 2 is essentially a replication of Experiment 1, designed to show that the structure of the semantic/syntactic space will emerge in the same way when new verbs are substituted for the ones previously tested. Experiments 3 and 4 then begin to investigate the nature of the semantic/syntactic mappings somewhat more closely, although of course we can not in a single experimental foray scratch very deeply at the enormous descriptive problems in this area. In our view, however, these latter two experiments do achieve some substantive results that allow preliminary theorizing about the kinds of semantic properties that are, and are not, formally marked in the syntax. For these results to be of interest to our ultimate concern with language learning, however, it would be necessary to show that they are potentially reproducible cross-linguistically; a very preliminary check on the procedure in another language (Italian) is therefore presented as Experiment 5. A final discussion pursues speculation on the nature of the syntax/semantics relationships in the verb lexicon and attempts to relate the experimental findings to language-learning issues.

EXPERIMENT 1

We selected 24 common verbs that represent some of the broad semantic distinctions that have been suggested in the linguistic literature and that we have just discussed. Our objective was to determine whether the syntactic structure of these verbs correlates with their meanings, and if so, how.

The experiment consisted of two subexperiments, conducted with different subject groups. Part A was designed to find out about the perceived semantic similarities among a set of verbs and then to characterize the semantic structure of the verbs based on these similarity measures. Part B was designed to discover the perceived syntactic similarities among the same set of verbs based on overlap in their licensed SubCat frames. The results of the two procedures were then compared using a regression analysis, bolstered by further cross-validation measures. The aim was to discover whether the syntactic partitioning (Part B) is predictive of semantic similarity (Part A). This general procedure was followed in all subsequent experiments reported.

Method

Part A: Assessing Semantic Similarity

The first task was to design a procedure by which subjects would tell us about the semantic similarity among sets of verbs. Obviously it overreaches the capacity (or concentration!) of lay subjects to order some largish set of verbs according to their semantic similarities and differences—this would be tantamount to asking them to construct a thesaurus. The experimental task would be far easier if reduced to one in which the subject makes judgments of similarity of the verbs two at a time, according to some scale. But we deemed it simpler yet to ask subjects to select, from three verbs presented to them, which was the least similar to the other two in meaning. By making explicit the context (the third verb) in which each pair of verbs is to be judged; this method makes the task more concrete and less burdensome than direct similarity judgments. This method for measuring semantic similarity is one which has been used for a similar purpose by Wexler (1970). Variations on this method of triads have been used in cognitive—developmental studies, again for reasons of simplicity (Miller & Gelman, 1983).

Subjects. The subjects were 28 undergraduates at the University of Pennsylvania, recruited through an introductory psychology class and paid for their participation in the study. All were native English speakers.

Stimuli. Twenty-four verbs comprised the experimental set. For a first assessment, we wanted to include verbs which represented differences both between and within broad semantic categories, and to use common verbs on which there had been prior linguistic work. Thus, the category and item choices were made on pretheoretic, intuitive grounds. Specifically, we selected *cognition* and *perception* verbs, *motion* verbs, *location* verbs, and *symmetrical* verbs. The 24 verbs are shown in Table 1. Inspection of the Table shows that the specific verbs crosscut these categories considerably (for instance, *collide* is surely a motion verb as well as a symmetrical verb; *arguing* involves cognition, etc.). At issue in this paper is whether the subjects' responses in the procedures to be described can provide a more reliable and valid way of thinking about the semantic organization of the verb lexicon.

Procedure. In each trial, the subjects were presented with a triad of verbs centered on a CRT screen and asked to indicate which of the three was "least similar in meaning" to the other two by pressing one of three keys as quickly and accurately as possible. They began with 10 practice triads, consisting of verbs not in the experimental set, followed by the list of experimental triads.

It was not feasible to ask subjects to respond to all 2024 of the triads (that is, all of the combinations of 24 verbs taken three at a time). The possible triads were therefore organized into different lists of 150 triads selected randomly. Each subject was presented with one such list. Thus 14 individuals were required to complete the full set of 2024 triads (in

TABLE 1
Verbs for Experiment 1

Perception/cognition verbs	
look	think
see	know
listen	explain
hear	believe
Motion/location verbs	
walk	stand
slide	balance
give	remain
take	live
Symmetrical verbs	
meet	tie
marry	collide
match	argue
equal	join

essence, the responses of 14 individuals add up to a single "meta-subject"). Two groups of 14 individuals (that is, two meta-subjects) participated in the procedure, with the order of presentation (of the triads in the list and of the verbs in each triad) reversed for the second group.

Scoring. Subjects in the triad procedure are, in effect, giving judgments of the degree of similarity of each pair of verbs in the context of each of the other verbs: Thus, an index of similarity could be computed for each pair of verbs by counting the number of times that this pair was judged to go together in the various contexts (of third verbs) in which it appeared. Since there were 24 verbs, each pair occurred in the context of 22 different third verbs. The similarity scores of each pair therefore could vary from 0 (the two verbs were never judged as similar) to 22 (the two verbs were always judged as similar).

To provide a more comprehensible characterization of the similarity pattern within the verb set, we subjected the similarity scores to a cluster analysis (CA; see Gordon 1981). CA refers to a class of methods for picking out natural "clumps" in similarity data. The algorithm we used locates overlapping clusters, in which each object (verb) can be a member of a number of similarity based groups.[7] This method is especially suitable if these clusters correspond to components of verb meaning, with each verb consisting of more than one such component.

Part B: An Assessment of the SubCat Privileges

The goal here was to get judgments of grammaticality from naive subjects; that is, judgments about which verbs occur naturally in which classes of SubCat frames.

Subjects. The subjects were 50 undergraduates at the University of Pennsylvania, who

[7] The method used here, OVERCLUS, is incorporated in the SAS statistical package. OVERCLUS is based on Sarle (1979), which in turn is based on the overlapping clustering model proposed by Shepard and Arabie (1979).

were recruited and paid for their participation. All of them were native speakers of English. None of these subjects participated in the semantic assessment procedure of Part A.

Stimuli. We compiled a list of 33 SubCat frames, encompassing all frames that seemed natural for at least one of the 24 verbs used in this study, and that might be capable of marking distinctions among them. The final list was based on compilations and discussions from Jackendoff (1983), Akmajian and Heny (1975), and the Brandeis Verb Catalog.[8] These frames are shown, along with examples, in Appendix A. In addition, six filler frames were included, producing 39 frames in all. Each of the 24 verbs was paired with each of these frames in a sentence, for a total of 936 sentences (including the filler frames).

For example, the verb *think* was presented in the sentences *John thinks, John thinks about Mary,* and so forth, for all 39 frames. All the other verbs were presented in the same 39 frame environments. The sentences were written to be as plausible in lexical content as possible. Thus, for the verb *give* we might choose *John gave the book to a student* but not *John gave the mongoose to a corkscrew.* Since all verbs were cast in all SubCat frames, many of these were ungrammatical or at least awkward, e.g., ?*John gave* or **John gave the student*. Of course it was just this naturalness as opposed to awkwardness that our subjects were asked to judge.

We should not minimize the difficulty of deciding on just which sentences should be presented as exemplars of each particular verb–frame combination. Suppose the sentence *John didn't sleep a wink* is included in the list given to subjects to judge. Surely this would have been judged grammatical, with the outcome that *sleep* would have been assigned as the kind of verb that accepts NP complements. Yet this kind of structure for *sleep* is certainly rare and quite obviously idiomatic (there is no passive **a wink was slept by John,* and no corresponding sentence with other NP's, such as **John slept a blink*). The decision to include or exclude such potentially idiomatic cases obviously will affect the structure of our findings, i.e., if the present sentence is included in the stimulus list, then *sleep* is going to come out syntactically closer to, say, *eat* and *see* than if this example is excluded.

In practice, our strategy was to exclude transparently idiomatic uses (*John kicked the bucket*), but to include all nonidiomatic uses that we could think of, even if these were rather rare or noncentral environments for the verbs. As an example of the latter, consider *John fought his opponent to his knees*. This *might* be a mere unsystematic idiom in English, but then again it might not be (after all, one can also say that *John fought his opponent to the ground,* so the usage is not restricted to a single and particular word sequence); so, such frames were not excluded.

Further, since we are interested in what types of structures subcategorize these verbs in the lexicon, we must be able to distinguish arguments of the verb (structurally, sisters to the verb) from adjunct phrases that are not part of the verb phrase (see Carlson and Tanenhaus, 1988). For example, the prepositional phrase (*in the cup*) in *John put poison in the cup* is certainly an argument of the verb *put,* since it is obligatory. However, not every PP is an argument: Virtually any verb can occur optionally with a temporal PP as in *John skated/ caught a mackerel/ travelled from Minsk to Pinsk/ realized that Bill was a mongoose/ in the morning*. If these clear adjunct phrases are included among the stimulus sentences, then no distinctions among verbs in their tendency to select PP's will be found. In practice, it can be difficult to distinguish between adjuncts and optional phrases that are nevertheless arguments of the verb. Our method has been to exclude all temporal phrases, as well as any other obvious adjuncts that make no distributional distinctions among verbs.

[8] The Brandeis Verb Catalog is a computer file of about 900 verbs together with information about their Subcat properties. The list was compiled by Lombardi, Maler, Grimshaw, and Jackendoff.

Procedure. Each subject was presented with a packet of sentences and instructed to rate each sentence on a scale from 1 (completely unacceptable) to 5 (completely acceptable). Acceptable sentences were defined as "sentences that seem natural, that you would not be surprised to hear spoken."

The sentences were presented by frame. All 24 sentences in a frame were randomly organized on a single page. This was done to make consistent judgments easier, by presenting subjects with both good and bad examples of a frame simultaneously. The 39 frames were randomly divided into 5 groups of 8 (including one repeated frame, discarded in these analyses), with the constraint that each group contain a reasonable variety of frames. A group of 10 subjects rated each 8-frame set, a total of 192 sentences. This procedure took about half an hour. The order of frames and sentences was random, and half of each group of subjects received the sentences in reverse order.

Scoring. The subjects' ratings of the sentences were converted to z scores to correct for differences in the way each subject used the rating scale. We then collapsed across classes of frames to define five initial frame variables, based on the acceptability scores described above, as follows:

1. PP—Each verb received a score that indicated its acceptability in frames with *prepositional phrases* (such as *John walked across the street*) as determined by the mean of the acceptability ratings for the 20 frames of the form NP V (NP) PP. These included intransitive sentences with the prepositions *to, from, toward, over, across, through, by, on, at, under, against, in, beside, between, with, for,* and *about,* and transitive sentences with the prepositions *to, from,* and *with.* As previously noted, verbs that occur in such frames have been said to encode locations, paths, and goals of objects in space.

2. SComp—Each verb received a score based on its acceptability ratings in sentence frames with *sentence complements*. SComp frames are defined here as frames in which the main verb is followed by an embedded sentence or verb phrase. These include embedded full sentences introduced by the complementizers *that, if, whether,* and *possessive+ing* ("poss – ing"), as in *I know (that) Bill was angry, John wondered if/whether Mary would be home,* and *John enjoyed her playing the piano,* and two untensed (infinitival) complements, as in *She believed him to be dead* and *I saw the man disappear over the hill.* Verbs that occur in these and related frames have been said to represent a relation between an actor and a proposition, thus encoding perception, cognition, and the causation of events, rather than, say, physical motion (compare **John gave that Bill was angry*).

3. 3-NP—Each verb received a score based on its acceptability ratings in sentences with three NP's in the clause (i.e., in which *three NP arguments* are specified); specifically, the four frames of the form NP V NP (P) NP. These include the double-object construction (*John gave Mary a book*) and three transitive frames with the prepositions *to, from,* and *with* (*John gave a book to Mary/took a book from Mary/filled the box with books*). Verbs having this structural property often include a semantic element that can be called transfer.

4. IPP—Each verb received a score based on its acceptability ratings in *imperative, progressive,* and so-called *pseudo-cleft* constructions. These three sentence frames are thought to admit active verbs: those that describe an actor doing something (e.g., *look, rebel,* and *accuse*); and to exclude stative verbs: those that describe a state of mind or circumstances (as in *see, know,* and *suspect*). Compare, for example, *Accuse/?Suspect him of treason!, John is looking at/?seeing the moon,* and *What John did was to rebel against the king/?know the answer.*

5. ICon—Each verb received a score that represented its naturalness in intransitive contexts with plural and conjoined NP subjects (as in *John and Mary met*) but not with singular unconjoined subjects (as in **John met*). This score was defined by the difference between the acceptability scores for the two frames NP and NP V and NP_{sing} V. As previously discussed, verbs that show a marked difference in their acceptability patterns for these two kinds of frames seem to encode symmetrical or reciprocal relationships.

To summarize, the original 33 frames were collapsed to yield five frame variables (PP, SComp, 3-NP, IPP, and ICon; see Appendix A). In each case either our intuitions or the work of such linguists as Vendler (1967, 1972), Talmy (1975), and Jackendoff (1978, 1983, 1987) had suggested that these variables, or something like them, would be relevant to the semantic structure of the set of verbs.

Results and Discussion

Our primary interest is in the relation between two characteristics of the verbs. One is the way in which they were judged to be similar in meaning. The other is the pattern of their syntactic attributes—the kinds of sentential frames in which they were judged to be natural. As we shall see, these two characteristics are related. Verbs that were judged to share certain syntactic properties were also judged similar in meaning.

Procedural Checks: Reliability

To assess the reliability of the triad choice method, we compared the results for the two subject groups used in Part A of the experiment. This was done using procedures developed by Hubert (1979; Hubert and Arabie, 1989) to avoid some difficulties with assessing the level of concord among proximity matrices (Carroll & Arabie, 1980). Following the procedures suggested by Hubert (1979), we derived an estimate of the concordance between the similarity matrices obtained from each group of subjects. This level of concordance is significant at the .001 level, as estimated by Hubert's procedure.[9] Given this result, the responses of the two groups were pooled.

To assess the reliability of subjects' acceptability judgments, we computed the Spearman rank-order correlation between pairs of subjects over all the sentences for each of the frame variables. This procedure gives a measure of agreement unaffected by the number of subjects involved (Guilford & Fuchter, 1973; Barsalou, 1987). The median correlations for these pairs were very high for the three frame variables PP, SComp, and 3-NP: .70, .68, and .77, respectively. The reliabilities of the ratings for the two frame variables IPP and ICon were much lower, with median Spearman ρ's of .48. Given this rather low level of reliability, these two variables were excluded from further analyses. But the question of why sub-

[9] Hubert's (1979) procedure for assessing concordance between two proximity matrices involves creating a reference distribution for the concordance statistic by (repeatedly) randomly permuting the rows and columns of the matrices to be reported. For expositional purposes, we also report a more familiar correlation coefficient: Spearman's $\rho = .81$. This correlation is of the same order as that found by Wexler (1970) using a similar method of triad similarity judgments.

jects disagree about the acceptability of certain forms is of considerable interest, and is one to which we will return in later discussion. The mean acceptability ratings for each verb on the three remaining syntactic variables are shown in Appendix B.

Comparing Syntax and Semantics: Overall Regression Analysis

We can now ask whether judgments of shared syntactic properties predict judgments of similarity of meaning. To answer this question, we first performed an overall regression analysis to predict similarity in meaning from acceptability ratings in the three sentence frames PP, SComp, and 3-NP. For this analysis, each *pair* of verbs was treated as a single observation. The dependent variable was the similarity score described before, ranging from 0 to 22. The three independent variables were indexed by the absolute value of the difference between the acceptability score on the three kinds of sentence frames for the two members of each verb pair. Again, this analysis involves comparing proximity matrices: this time, a semantic similarity matrix is predicted on the basis of three syntactic difference matrices. Since the ordinary significance testing associated with a multiple regression is inappropriate in this case (Carroll & Arabie, 1980), the significance of the level of prediction indexed by the multiple correlation was assessed using the randomization procedure proposed by Hubert and Arabie (1989). The results were in line with our general approach. The three frame variables (PP, SComp, and 3-NP) significantly predicted the semantic similarity scores ($R = .36, p < .001$), with small differences in syntactic scores predicting high similarity in meaning.

The predictive value of this regression model is quite respectable, given a number of obvious sources of additional variance: The three frame categories we selected are rather crude and represent only a fraction of the frame distinctions that can subcategorize verbs. In addition, we would hardly expect all semantic properties to be exhibited in the syntax, a point to which we will return in Experiment 3.

Comparing Syntax and Semantics: Cluster Analysis

The regression analysis just described shows that there is an overall relationship between the subcategorization properties of the verbs and their similarity in meaning. Can we specify the nature of this relationship in more detail? To answer this question, we performed the cluster analysis of the similarity scores described above and then tested whether the semantic clusters could be characterized on the basis of their syntactic acceptability scores.

As described previously, the (overlapping) cluster analysis was based on the similarity scores. The resulting clusters are shown on the left-hand column of Table 2. In essence, the clusters represent the structure implicit in the subjects' judgment of the semantic relationships among the verbs. The cluster weights, shown in the second column of the Table, represent the importance of each cluster in reproducing the original similarity scores. These nine clusters provide a good representation of the similarity data, yielding an overall R^2 of .75. (This same—rather arbitrarily chosen—level was used in each experiment as a cutoff for the number of clusters analyzed.)

Later, we will attempt to characterize these clusters semantically. But first we will ask about the extent to which these semantic clusters can be analyzed in syntactic terms. To do this, we conducted separate analyses of variance for each semantic cluster, using membership in each cluster as the independent variable and testing whether the members of each cluster differed from nonmembers on their syntactic scores. Given the positive findings in the overall regression analysis described above, it is clear that there is a relationship of some kind between the semantic similarity and

TABLE 2
Clustering and ANOVA Results, Experiment 1

		Frame variables		
Cluster	Weight	PP	SComp	3-NP
1. walk slide stand balance collide argue	4.17	$F = 7.29$*	$F < 1$	$F < 1$
2. think know explain give take stand balance believe remain live marry match equal tie join	3.96	$F = 6.48$*,[a]	$F = 1.39$	$F < 1$
3. balance meet marry match equal tie collide join	7.40	$F = 10.00$**,[a]	$F = 8.33$**,[a]	$F < 1$
4. look see listen hear think know explain believe argue	7.62	$F < 1$	$F = 50.6$***	$F < 1$
5. look see listen hear think know believe remain live meet	4.10	$F < 1$	$F = 4.55$*	$F = 3.74$
6. explain give take argue	5.20	$F < 1$	$F < 1$	$F = 10.89$**
7. walk stand balance remain equal	4.19	$F = 2.42$	$F = 2.99$	$F = 3.17$
8. look see walk slide take stand meet collide	4.66	$F = 2.84$	$F < 1$	$F < 1$
9. walk slide give remain meet marry match tie collide argue join	2.74	$F < 1$	$F = 3.99$	$F < 1$

* $p < .05$.
** $p < .01$.
*** $p < .001$.
[a] Verbs in this group tend to have *low* scores on this variable compared to verbs not in the group.

subcategorization properties of these verbs; the post-hoc comparison of probabilistic semantic clusters and subcategorization properties was carried out in order to allow a description of that relationship.[10]

The results of each of these analyses are shown in Table 2. Columns 3, 4, and 5 show the univariate *F* values indicating the magnitude of the difference between the syntactic scores of verbs in and out of each cluster. Some of the findings that emerge from these cluster ANOVAs are quite strong: In several cases, there are marked differences in the syntactic behavior of the verbs that were independently distinguished on the basis of their membership in semantic clusters.

To summarize: In both of the analyses just presented, powerful correlations were found between subjects' semantic partitioning of a set of verbs and other subjects' syntactic partitioning of that same set of verbs. The correspondences between these two partitionings, performed by different subjects doing different tasks, suggest that the clause structures represent aspects of verb semantics rather well. More specifically, several semantic groups can be characterized by their distinctive syntactic properties. Overall, then, the results appear to document strong syntactic/semantic correspondences in the psychological organization of the lexicon. Before discussing the nature of these correspondences, it's important to consider an alternative interpretation for all the results we have reported: It might be that, contrary to instructions, subjects in both parts of the experiment performed the *same* analysis of the verb items. The subjects asked to judge semantic relatedness might have considered the syntactic overlaps among these verbs and made their responses at least partly on that basis. After all, if we are at all right in our conjectures about

[10] This analysis departs somewhat from a strict, experimental use of ANOVA: first, the assumption that the membership of the groups is determined without error is violated and, second, the unequal distribution of verbs in versus not in each semantic cluster renders the usual assumptions of the significance tests problematic. Nevertheless, given that we already have evidence of a relationship between the semantic similarity and subcategorization properties of these verbs, this test was deemed reasonable for descriptive purposes. Also, another, related analysis was carried out: a discriminant analysis for each cluster, classifying each verb (*in* versus *out* of the group) based on a linear combination of the three syntactic variables PP, SComp, and 3-NP. The one of those three variables most highly correlated with the discriminant function is considered mostly responsible for whatever degree of prediction results. For each case discussed in this paper, the results of the discriminant analysis duplicated those of the ANOVAs quite closely. That is, for each positive result in the ANOVA, the same syntactic variable could be used to substantially (greater than chance) predict the membership of the same semantic cluster. A few isolated small differences in the findings using the two methods will be pointed out as they arise. The fact that these two analyses agree, despite their different strengths and weaknesses, provides some additional validation for our current description of the important relationships between syntax and semantics for these verbs.

verb–lexical organization, and if subjects are in implicit possession of this organization, then attending to syntactic overlap is one way of reaching a decision about semantic relatedness. Symmetrically, subjects in the syntactic task might have considered only the meanings of the sentences, e.g., their judgment that *John took to the store* was ill formed might have been based solely on semantics (i.e., on the thematic roles required, given the meaning of *take*). If so, then it is no surprise that the results of the two tasks correlated closely.

We cannot wholly eliminate such interpretations of the subjects' behavior, but it seems implausible on several grounds that those in the two experimental groups responded as if to the same instructions. Subjects were interviewed after performing these tasks and none ever suggested use of these perverse strategies. More important, there are systematic differences (in this and the following experiments) in the structure of data for the two tasks: In addition to the semantic clusters related to the syntactic variables, there are always additional semantic clusters unrelated to these (or to any other syntactic variables we have been able to think of). Finally, convergent procedures in our lab studying these same issues are not subject to these alternate interpretations, and yet yield the same kind of result.[11]

Semantic Interpretation of the Frame Variables

We turn now to some preliminary conjectures about the semantic values of each of the frame variables, culled from an examination of the verb items in the clusters for which these variables differ. We will limit our attention to those clusters whose membership indicates high scores on each syntactic variable rather than those which are characterized by the absence of the corresponding syntactic property. This seems reasonable because, while possession of some syntactic feature might well mark some well-defined semantic property, the lack of the same syntactic feature is less informative. Putting this another way, one can plausibly claim rather refined and useful knowledge about a verb's meaning if one realizes that it is a motion or a perception verb. But—depending on how many such classes of verbs there are—the information that some verb is "not a perception verb" hardly narrows down the choices for its meaning.

Prepositional phrases (*PP*). Membership in cluster 1 of Table 2 was

[11] Specifically, both child and adult subjects in these experiments are asked for interpretations of scenes with and without sentence-structural evidence. The response characteristics vary radically in these two conditions (Fisher et al., forthcoming). In another experiment, reminiscent of Zwicky's remarks in the opening quotation of this paper, subjects' semantic descriptions of sentences containing known verbs vary as a function of the syntax provided (Fisher, in progress).

characterized by high scores on the syntactic variable PP. This cluster consists of the verbs *walk, slide, stand, balance, collide* and *argue.*[12] Although these verbs differ widely in their full construals, most of them share a notional component: They pertain to position in or motion through space, with the PP itself representing the source, path, or goal of that motion or position.[13]

Sentence complements (SComp). High scores on the syntactic variable SComp corresponded to membership in two semantic clusters. Membership in cluster 4 in Table 2, containing all and only the verbs of cognition and perception in the set of verbs, was characterized by high scores on SComp. Cluster 5 showed much the same pattern, overlapping substantially with cluster 4. These findings are just what we would expect if, as Jackendoff suggests, the syntactic/semantic relations are quite straightforward. Cognition and (some) perception verbs encode a relationship between an agent and a proposition (e.g., *John sees that Mary is tall, John thinks that Mary is tall*); transparently enough, the syntactic encoding of the proposition is a clause.[14] In contrast, verbs of physical motion encode relations among objects and do not accept sentential complements (**John gives that Mary is tall*).

3-NP frames. The ANOVA results showed that cluster 6 in Table 2, consisting of the verbs *give, take, explain,* and *argue,* is positively related to the syntactic variable 3-NP. While this group crosscuts the a priori semantic fields—motion versus cognition verbs—from which these verbs were chosen, subjects judged them as sharing some aspect of their mean-

[12] One caveat must be remarked on in interpreting these results. Since this semantic group is small relative to the experimental set of verbs, the statistical test associated with the ANOVA is especially troublesome for this case, as is the stability of the discriminant function computed for comparison purposes. Thus, interpretations of such small groups must be taken as somewhat uncertain until they can be backed up with similar results from more evenly divided groups of verbs: See Experiments 2 and 3 for corroborating results for the variable PP. The result reported for the variable 3-NP in Experiment 1 is also subject to this problem but, again, concordant findings are presented in Experiments 4 and 5.

[13] One member of this cluster, the verb *argue,* clearly does not fit this semantic/syntactic generalization. That is, it is not at all well-characterized as a motion or location verb. This oddity should not be surprising. As we acknowledged in introducing the experimental procedure, the semantic similarity data are heavily affected by the context (of all verbs in the experimental set) of third verbs against which the similarity of any verb pair is assessed by the subject. Combining the verbs into semantic groups on the basis of subjects' semantic similarity judgments, under this experimental constraint, introduces some error and imprecision into the outcomes. Given this, interpretations of the semantics of these clusters must rest on the overall composition of the group, and can give no simple or direct explanation of apparent outliers, such as *argue* in the present group.

[14] It turns out that not *all* verbs of perception take sentence complements (*see* does but *look* does not), a point to which we will return in Experiment 3.

ing. Preliminarily, we have labeled this meaning component transfer: *Giving* and *taking* involve the transfer of objects across locations in space, and *explaining* and *arguing* involve the transfer of ideas across speaker/listeners.

Additional semantic clusters. Finally, some of the clusters that represent the semantic structure of this group of verbs are not positively related to the syntactic variables we examined, and yet can be interpreted as potential aspects of similarity in verb meaning. Consider cluster 3, which contains all the symmetrical verbs in the set (*balance, meet, marry, match, equal, tie, collide, join*). We know from prior analyses (Gleitman, 1965) and experimental evidence (Gleitman et al., forthcoming) that there are strong syntactic correlates of this semantic property. Yet the syntactic variables that we tested were not sufficient for picking this up (except the uninformative negative correlation with PP for this cluster, see Table 2). For other clusters, there may be no significantly correlated syntactic variable. Consider cluster 7 in Table 2 (*stand, balance, remain, equal,* and *walk*). Four of these five verbs (*walk* is the obvious exception, see again footnote 12) are semantically related in that they pertain to a stable location or state of affairs (roughly, Jesperson's 1927/1956 verbs of being and becoming, and Jackendoff's 1978 be and stay verbs), and yet are not correlated with any single syntactic property that we know of. The existence of such interpretable clusters that are difficult to define in syntactic terms, while hardly conclusive, supports the view that the subjects in the triad task are making *semantic* judgments rather than—in contravention of the task instructions—reporting implicitly known subcategorization relations.

Summary

The results of Experiment 1 show that certain syntactic variables are strongly related to the semantic structure of a set of verbs: The semantic similarity scores were predicted to a significant degree by the SubCat variables. Further, by inspecting the clusters of verbs that were predicted by these syntactic variables, we made some preliminary conjectures about their semantic correlates. The experiments that follow are designed to examine the role of these same syntactic variables in more detail.

EXPERIMENT 2

The present experiment removes certain barriers to interpreting the results just reported by assessing the degree to which the semantic/syntactic relationships hold up for new choices of verb items. For example, since *see* and *feel* are both verbs of perception, any syntactic correlate of this meaning relation should show up again if *feel* is now tested in the same way that *see* was previously tested.

TABLE 3
Verbs for Experiment 2

Perception/cognition verbs	
touch	understand
feel	guess
observe	remember
glance	suggest
Motion/location verbs	
crawl	rest
run	stay
throw	wait
jump	sit
cut	
Symmetrical verbs	
attach	
fight	separate

Method

A new set of verbs (shown in Table 3), chosen to fit the same a priori semantic classes as those in Experiment 1, was examined using the method described in Experiment 1. Semantic similarity relations among the verbs were assessed using the triad method, and their tendency to occur with the three frame classes SComp, PP, and 3-NP was assessed as in Experiment 1.[15]

Results and Discussion

As for Experiment 1, judgments of both kinds (semantic and syntactic) were quite reliable across subjects: the two proximity matrices obtained in the triad task were in close concordance ($p < .001$ as estimated by Hubert's, 1979, method; Spearman's $\rho = .78$), and subjects agreed in their ratings of sentences within each of the three frame classes (median Spearman ρ's for pairs of subjects were .74, .72, and .66, for PP, SComp,

[15] Part B of this method differed from Experiment 1 in omitting some frames: the filler frames were dropped, and those that made up the variables ICon and IPP were omitted also, given the low reliability of their ratings. The variables PP, SComp, and 3-NP were composed exactly as before, with the exception that the variable 3-NP was made up of three frames rather than four: the frame [NP V NP [with NP]] was left out due to difficulties in writing syntactically and semantically unambiguous sentences with the new verb items. In Part A, given a set of 20 verbs, eight subjects were required to complete the set of 1140 triad judgments. Again, two sets of eight, or two meta-subjects were run. In Part B, the 27 frames used to make up the 3 frame variables were combined with each verb; the resulting 540 sentences were divided into two subsets of 260 and 280 (one based on 13 and the other on 14 of the sentence frames).

and 3-NP, respectively). The scores for each verb on these three syntactic variables are shown in Appendix B.

The overall regression analysis, with significance of prediction again determined by Hubert and Arabie's (1989) permutation method, shows that semantic similarity scores are strongly predicted by the verbs' shared syntactic properties ($R = .56, p < .001$). The clustering solution for these verbs is shown in Table 4, along with the results of an ANOVA to test whether each cluster could be characterized in terms of its syntactic behavior. As in Experiment 1, several of these semantic clusters are also marked by their syntactic similarity.

In both Experiments 1 and 2, semantic similarity judgments predicted which verbs occur freely with PP's, with sentence complements (SComp's) and with 3-NP's. The fact that the same syntax/semantics mappings were found in both experiments allows us to reevaluate the tentative semantic interpretations suggested in discussing Experiment 1; once again the positive results from the cluster ANOVAs can be exam-

TABLE 4
Clustering and ANOVA Results, Experiment 2

		Frame variables		
Cluster	Weight	PP	SComp	3-NP
1. crawl run throw jump cut fight	6.15	$F = 14.64$***	$F = 3.19$	$F = 6.90$*
2. glance understand guess remember suggest attach separate	3.81	$F = 16.03$***,a	$F = 3.68$	$F < 1$
3. touch cut attach separate	7.63	$F = 4.26$*,a	$F = 2.49$	$F < 1$
4. touch crawl run throw jump rest sit fight	3.41	$F = 8.84$**	$F = 6.87$*,a	$F < 1$
5. feel observe understand guess remember suggest	7.12	$F = 5.81$*,a	$F = 357.6$***	$F < 1$
6. rest stay wait sit	10.04	$F = 1.04$	$F = 2.11$	$F = 4.84$*,a,b
7. touch feel	15.13	$F < 1$	$F < 1$	$F < 1$
8. observe glance	11.77	$F < 1$	$F < 1$	$F < 1$
9. touch glance	10.13	$F < 1$	$F < 1$	$F = 1.28$
10. observe understand wait	4.30	$F = 1.05$	$F = 3.12$	$F < 1$

* $p < .05$.
** $p < .01$.
*** $p < .001$.
[a] The members of this semantic cluster tend to have *lower* scores on this frame variable than verbs not in this cluster.
[b] The membership of this semantic cluster was not found to be predictable in the corresponding discriminant analysis. The best discriminant function based on the syntactic variables PP, SComp, and 3-NP correctly placed only 75% of the verbs, less accurate than guessing based on the prior probabilities of group membership (.80).

ined with these semantic interpretations in mind. With one partial exception, those interpretations are bolstered by the new findings.

Prepositional Phrases (PP)

Membership in clusters 1 and 4 (Table 4) was characterized by high scores on the variable PP. The verbs in these groups overlap considerably (*crawl, run, throw, jump, cut,* and *fight,* and *touch, rest,* and *sit*) and form a natural group with the relevant cluster of Experiment 1 (*walk, slide, stand, balance, collide,* and *argue*). Although these verbs differ in many aspects, they all share the property of encoding position in or motion through space, as suggested in the discussion of Experiment 1.

Sentence Complements (SComp)

Membership in cluster 5 in Table 4 is predictive of acceptability in SComp frames and contains the verbs *feel, observe, understand, guess, remember,* and *suggest.* As predicted from the findings of Experiment 1, all of these verbs pertain to perception and cognition. Two verbs (*touch* and *glance*) that we included in this set preexperimentally (see Table 3) are excluded from this cluster (appearing instead as cluster 9, see below).

3-NP Frames (3-NP)

The ANOVA results for the variable 3-NP were also quite similar for Experiments 1 and 2. Cluster 6 of Experiment 1, correlated with 3-NP frames, consists of *explain, give, take,* and *argue.* We tentatively characterized the semantic property predicted by this frame variable as (mental or physical) transfer. In Experiment 2, membership in cluster 1 (the same cluster that was correlated with PP) is found to be related to high scores on the 3-NP variable.

Despite the generally strong replication of findings between Experiments 1 and 2, there is a single regard in which the 3-NP results weaken, or put in question, one prior interpretation. This has to do with the semantic labeling of the 3-NP syntactic variable. Notice that cluster 1 is correlated with this syntactic variable. Three verbs in this cluster, consistent with our prior interpretation, pertain to transfer when they occur in 3-NP frames: *throw* (as in *John threw the bomb out to sea*), *cut* (as in *John cut the cast off his arm*), and *fight* (as in *John fought his enemy to his knees*). But three other verbs in this cluster (*crawl, run,* and *jump*) have nothing to do with transfer and are not 3-NP verbs. Clearly, the complication here has to do with the fact that this cluster is a composite, correlated with two frame variables (PP and 3-NP)—and therefore something of a semantic monster as well. In short, the transfer interpretation derived in Experiment 1 for the 3-NP variable is only weakly supported in

Experiment 2, necessitating further analysis (for which, see Experiments 4 and 5 following).

Additional Semantic Clusters

Finally, we again find some meaningfully interpretable clusters that cannot be characterized on the syntactic variables we tested. Cluster 6 (like cluster 7 of Experiment 1) contains verbs of stable location (*rest, stay, wait, sit*). Although Jackendoff (1978) suggests that there are syntactic correlates of this class, the sentence frames we provided to the subjects giving grammaticality judgments did not include the appropriate distinguishing environments to test this claim. Other clusters in Table 4 may represent cases of semantic relations that are not represented in the facts about subcategorization. For instance, cluster 7 contains verbs of tactile perception (*touch* and *feel*) while cluster 8 contains verbs of visual perception (*observe* and *glance*). Cluster 9 consists of two verbs of different sensory modalities (*touch* and *glance*); however, these verbs seem to share a manner component, implying a very brief exploration. Thus, again the semantic judgment task yields a considerably richer partitioning of the verb set than the syntactic judgment task—suggesting that the subjects in these two procedures were indeed performing different tasks.

In summary, Experiments 1 and 2, which used different verbs chosen from several far-flung semantic domains, show that certain syntactic variables are strongly related to the semantic similarity between verbs.[16] In addition, an inspection of the verb clusters that were positively related to these syntactic variables provides additional support for two of the three semantic conjectures proposed in the discussion of Experiment 1. The third such conjecture (pertaining to transfer) was rendered problematical by the results of Experiment 2.

EXPERIMENT 3

The experiments just described showed that our procedures have some

[16] A procedure comparing the results of these experiments directly was also carried out: This comparison experiment combined verbs from Experiments 1 and 2 in match-to-sample triads, to test whether verbs from the PP-related semantic clusters and from the SComp-related semantic clusters form coherent semantic groups across the two experiments. In the match-to-sample triads, the choice items were always a PP verb and an SComp verb, both chosen from Experiment 2. On half of the triads the sample item was a PP verb drawn from Experiment 1; on the other half, it was an SComp verb, also drawn from Experiment 1. Ten subjects were asked to choose the one of the two choice verbs that was most similar in meaning to the sample verb. On 94% of their judgments, these subjects matched verbs within rather than across syntactic class. Thus the results of Experiments 1 and 2 are as congruent as they look. Not only do the same syntactic variables turn up as related to the semantic clusters in both cases, but the verbs in the relevant clusters form coherent semantic groups across the two experiments.

useful degree of resolving power and are quite reliable over varying choices of verbs. This puts us in a position to examine more closely some of the syntactic/semantic mappings discovered there. Specifically, we now ask how the syntactic variables PP and SComp are related to the logic of certain verbs.

It has been proposed that motion/location and certain perception verbs are semantically related in a way that maps onto the syntactic property of occurring with PP's (Gruber, 1967; Jackendoff, 1983) and that perception and cognition verbs are related in meaning in a way that maps onto the syntactic property of accepting SComp's (Vendler, 1972; Landau and Gleitman, 1985). These groups of verbs might be characterized as having to do with spatial extent and with states or acts of the mind, respectively. Experiments 1 and 2 provided preliminary evidence for these relationships between structure and meaning.[17]

We now attempt to refine these preliminary semantic generalizations by examining the syntactic and semantic behavior of a more narrowly chosen set of verbs—verbs of perception. We chose these as a likely source of information about the semantic generalizations, for taken as a group they seem to be associated with both the SComp and the PP syntactic variables; but also because, when we consider these verbs individually, it becomes clear that they differ in syntactic detail. For example, *look* occurs with many PP's (e.g., *look at the moon, look under the table, look beneath the surface*). In contrast, *hear* does not (compare **hear at the moon, *hear under the table*). On the other hand, *hear* is perfectly acceptable in SComp frames (*I hear that John is getting married*), while *look* is not (**I look that John is getting married*). Different subsets of perception verbs evidently possess different syntactic properties with regard to acceptability in PP's and SComp's. The question now is whether we can uncover semantic distinctions among these perception verbs that are related to these syntactic differences between them.

What should we expect to find in this regard? We believe that a relevant distinction is between perceptual *exploration* versus perceptual *achievement*. Some of the perception verbs describe an attempt to explore or search for some object or event (*looking* and *listening*), while some others describe the perceptual achievement that is a consequence of this exploration (for example, *seeing* or *hearing*). On the face of it, verbs of perceptual exploration (such as *look*) would be expected to be acceptable in

[17] The results from Experiments 1 and 2 match the generalizations just described with one exception: We have only very scanty evidence from these two studies that perception and motion verbs are grouped together in a way that maps onto occurrence with PP's. That any particular combination of verbs should not show up in those initial studies is not too surprising, given the small numbers of perception and motion verbs included.

PP frames (in this respect, to behave much like motion verbs, as Gruber suggested), while verbs of perceptual achievement (such as *see*) would be expected to be acceptable in SComp frames (in this respect, much like verbs of cognition, as Vendler suggested). The main purpose of Experiment 3 is to provide some evidence for this conjecture.

Verbs of perception can also provide further evidence on the question whether the subjects really are attempting two quasi-independent classifications of the verb set. This is because the most obvious distinction among the perception verbs is probably not encoded in the syntactic structures that the verbs accept (for reasons we shall discuss). This distinction concerns the specific sensory modality that is the source of the perception; that is, *looking* involves the eyes, *listening* involves the ears, and *touching* involves the hands. We expect this semantic distinction to show up in the triad task, i.e., for there to emerge clusters related to sensory source. The results of Experiment 2 begin to support this conjecture: there, several clusters unrelated to syntax could be characterized as related to the manner and modality of perception. If this semantic factor is again not reflected in the judgments of grammaticality (i.e., if frame variables do not predict these clusters), we have further evidence that subjects in the syntactic and semantic conditions are attempting different partitionings.

Method

Part A: Semantic Similarity

Subjects. Twenty-eight students at the University of Pennsylvania served as subjects. All were native speakers of English and were paid for their participation.

Stimuli. Twenty-four perception verbs were selected, with the aid of a thesaurus, to reflect three a priori semantic distinctions: (a) the verbs were chosen to represent each of the traditional five senses (vision, hearing, etc.); (b) they were further chosen to fall into two groups based on the distinction between perceptual exploration, as in *look,* and perceptual achievement, as in *see.* (c) A final distinction concerned the degree of specificity of the verbs, from general perception verbs such as *perceive* and *explore,* which do not specify modality or manner, to very specific ones such as *handle* and *glimpse* that specify both modality (hand versus eye) and manner of perception (e.g., continued versus brief inspection). The complete set is shown in Table 5.

Procedure. Each subject made judgments on 150 of the possible 2024 triads, and two groups of 14 individuals (two meta-subjects) made judgments for the entire set. Similarity scores were computed as in Experiments 1 and 2.

Part B: Syntactic Variables

Subjects. Six graduate students at the University of Pennsylvania served as subjects. All were native speakers of English and were paid for their participation. Some of these subjects had also participated in Part B of Experiment 2.

Stimuli. The sentences were created by placing each verb in each of 22 frames: 12 PP frames, 6 SComp frames, and 4 filler frames. These frames are shown, along with examples, in Appendix C. The lists of PP and SComp frames contain most of the ones used in Exper-

TABLE 5
Verbs for Experiment 3

	Exploration	Achieved perception
No modality specified	explore	perceive
	examine	sense
Modality specified	look	see
	listen	hear
	taste	(taste)
	smell	(smell)
	touch	feel
Modality and manner specified	gaze	glimpse
	glance	sight
	peer	scent
	peek	
	savor	
	sip	
	sniff	
	finger	
	handle	

iments 1 and 2, although some were omitted if we judged that they applied to none of the verbs in this set. The resulting 528 sentences were written to be as plausible as possible.

Procedure. The sentences were rated as in Experiments 1 and 2. Each subject rated all the sentences, presented by frame as before, a process that took about 45 min. The scoring procedure was the same as that used in Experiments 1 and 2.

Results and Discussion

Procedural Checks: Reliability

The concordance between the similarity scores given by the two groups of subjects is comparable to the match between subject groups found previously ($p < .001$ by Hubert's, 1979, method, Spearman's $\rho = .76$), so all further analyses are based on similarity scores pooled from the two groups of subjects.

The scores for each verb on the syntactic variables PP and SComp are given in Appendix B. Reliability of the subjects' judgments was assessed as before, by computing the median Spearman correlation between pairs of subjects. This resulted in median Spearman ρ's of .70 and .76, for PP and SComp sentences, respectively.

Comparison of Syntax and Semantics

As in Experiments 1 and 2, an overall regression analysis was carried out; again, the semantic similarity between pairs of verbs could be significantly predicted on the basis of their shared syntactic behavior ($R = .17$, $p < .025$). Notice that the prediction afforded by this model (as measured by the multiple correlation) is lower than in previous experiments, in line with the intuition that the main semantic organizing principle of this set of verbs, sensory modality, may not be represented in the phrasal syntax. Nevertheless, it appears that some additional semantic distinctions among these verbs are related to their syntactic behavior.

To characterize the syntactically marked distinctions in greater detail, we carried out a number of ANOVAs to compare cluster membership and frame variable scores. The results are summarized in Table 6. As the Table shows, three of the clusters were significantly related to the two SubCat variables PP and SComp, while three others were not. We will consider both the effects and the noneffects, beginning with the role of sensory modality.

The effect of sensory modality. The composition of the clusters shown in Table 6 clearly reflects the sensory modality of the various perception verbs. All of the verbs involving visual perception are members of cluster 2, auditory perception verbs are in cluster 6, tactile perception verbs are in cluster 5, and verbs involving taste and smell are in cluster 4. Note that three of these clusters (specifically clusters 4, 5, and 6) have no relation to the syntactic variables defined here, bolstering the indications that subjects' judgments in the triad task were semantic but asyntactic.

TABLE 6
Clustering and ANOVA Results, Experiment 3

Cluster	Weight	Frame variables	
		PP	SComp
1. perceive sense listen taste smell touch see hear feel sniff sight scent	3.32	$F = 1.53$	$F = 17.11$***
2. look see gaze glance peer peek glimpse sight	8.75	$F = 11.09$**	$F < 1$
3. explore examine perceive look listen see gaze peer	4.20	$F = 4.34$*,[a]	$F < 1$
4. taste smell savor sip sniff scent	8.38	$F = 1.60$	$F < 1$
5. explore examine touch feel finger handle	9.74	$F < 1$	$F < 1$
6. listen hear	13.07	$F < 1$	$F = 1.22$

* $p < .05$.
** $p < .01$.
*** $p < .001$.
[a] The membership of this semantic cluster was not found to be predictable in the corresponding discriminant analysis: the best discriminant function based on the two variables PP and SComp correctly placed only 66.7% of the verbs, no improvement over a guess based on the prior probabilities of group membership (.667).

Sensory modality and prepositional phrases. Recall that verbs that accept a large number of PP's were those that scored high on the PP variable. For example, *look* occurs with various PP's (*John looks at/over/through/ beyond/toward/away from the window*) and so scored high on this variable, while verbs like *listen* and *smell* which take few or no PP's scored low on this variable.

The syntactic variable PP was found to correlate with just one of the clusters that concern sensory modality: cluster 2, whose members are the verbs of vision. Clusters 4 (verbs of taste and smell), 5 (touch), and 6 (audition) are unrelated to the PP variable. Do these findings imply that the syntactic variable PP is a straightforward reflection of the semantic property vision? The answer is no. One reason to reject such a conclusion is that the results of Experiments 1 and 2 show that many motion verbs (e.g., *walk*) also appear in PP-related clusters. The conclusion drawn there was that the PP variable is interpretable as spatial motion or location. The plausibility of that interpretation is in fact bolstered by the present finding that, among verbs of perception, the visual ones are those related to PP: After all, vision is the spatial modality par excellence and so should, and does, appear in a wide range of PP constructions expressing locations, paths, and goals in space (Jackendoff, 1983; and see Gruber, 1967, for a discussion that emphasizes the relation between motion verbs and verbs of visual perception).

Perceptual exploration versus perceptual achievement. Table 6 also shows a strong relation between membership in cluster 1 and the syntactic variable SComp. Why should this be so? We previously argued that verbs that take sentence complements tend to be verbs of cognition (such as *understand* or *believe*) that refer to mental acts or states of mind. Since an act of perceiving is a mental act, resulting in a perceptual state, we might expect that just about all perception verbs, like just about all cognition verbs, would accept SComp.

However, as is well known, and reflected in our own data, not all perceptual verbs accept sentence complements. This syntactic distinction appears to reflect a semantic distinction between verbs that describe attempts to perceive (such as *look* and *explore*) and verbs of perceptual achievement (such as *see* and *perceive*). Notice that the verbs of cluster 1, associated with the SComp variable, are virtually always interpretable as verbs of achieved perception.[18]

[18] The clearest cases of attempted perception in the experimental set are, as predicted, absent from cluster 1 (*look, explore, examine, sniff, finger, handle*). The verb *listen* is the only clear exception to this generalization. And the clearest cases of achieved perception in the experimental set are, as predicted, present in cluster 1 (*see, perceive, hear, feel*). But notice that a fair number of the verbs in cluster 1 are amenable to both the attempted and the

The results of this experiment strengthen and extend the results of the earlier experiments. First, they suggest that some quite refined distinctions within a semantic domain are formally marked in the structure of clauses. It appears that syntactic variables do more than distinguish between such broad domains as motion and cognition; they also make distinctions within more narrowly drawn domains. Specifically, we find that the syntactic properties of occurring with PP's or SComp's correspond to different semantic groups within the set of perception verbs.

Our interpretations of these recurring syntax/semantics mappings now extend to a new set of verbs. First, the results of Experiments 1 and 2 were consistent with the conclusion that sentence complement frames (SComp) mark a relation between an actor and a proposition, and therefore encode mental events. Here we find that only certain perception verbs accept SComp frames; namely, the ones like *see* that describe states of achieved perception. Reasonably enough, verbs of perceptual exploration are treated syntactically as physical acts. That is, *look* and *listen* behave syntactically like *go* and other motion verbs in this regard.

Second, we conjectured from the results of Experiments 1 and 2 that only verbs encoding spatial relationships such as motion and location occur freely with spatial PP's. In the case of perception verbs, it turns out that verbs of the centrally spatial perceptual modality (vision) accept PP frames while other perceptual verbs do not.

EXPERIMENT 4

Thus far we have considered in some detail two of the three syntactic/semantic mappings uncovered in Experiments 1 and 2; namely, the proposed correlation between sentence complement frames and mental states and acts, and between prepositional phrase frames and spatial relations, including motion and spatial perception. We now consider the third of these syntactic variables: acceptability in the 3-NP frames. As shown by the results of Experiments 1 and 2, this variable (3-NP) was represented in the semantic structure of the verbs, and so far has been interpreted as encoding transfer. The present experiment attempts to assess this relationship further, using a new set of verbs.

The verbs selected for a further examination of the 3-NP property are

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achieved interpretations, for (outside the crucial visual modality) many languages—including English—use a single verb for both interpretations. For example, one might use *smell* to describe both the attempt to smell and success in getting the scent. Since the question put to subjects in the grammaticality judgment task was whether a verb such as *smell* could appear in certain SComp constructions (not the question whether the verb always and only appears in such constructions), our prediction, supported by the findings, is that the ambiguous verbs would be among those associated with the SComp frame.

all members of the class of cognition verbs, but differing on the 3-NP variable. We will address two questions: First, do the meaning similarity ratings of these verbs reflect their occurrence with 3-NP frames? Second, given such a semantic distinction, does it accord with our previous interpretations? That is, is transfer an appropriate semantic label for the 3-NP variable?

By hypothesis, there are "one-head" cognition verbs, where the mental act or state is within a single mind and there is no transfer of ideas (e.g., *think*); such verbs ought not to occur in the 3-NP frame if, truly, 3-NP encodes transfer. The reverse should hold for "two-head"—or communication—cognition verbs (e.g., *argue*) in which the ideas are transferred from mind to mind. In short, we now propose that the local interpretation of transfer in the domain of mental verbs is communication—the transfer of ideas.

Method

Part A: Semantic Similarity

Subjects. Sixteen undergraduates at the University of Pennsylvania served as subjects. All were native speakers of English and were paid for their participation.

Stimuli. Twenty verbs formed the experimental set. The criteria for choosing the verbs were that, in our preexperimental judgment, (a) they accept some form of SComp frame, (b) they are cognition verbs on some reading, and (c) half of them accept 3-NP frames, while half do not. As in the previous experiments, we used only fairly common verbs, tried to avoid ambiguous verbs, and covered a wide range of what we saw as the semantic possibilities within these constraints. The complete list of verbs is shown in Table 7.[19]

Procedure. With 20 verbs, there are 1140 possible triads. Each subject was shown 150 of these, and two groups of eight subjects (two meta-subjects) made judgments for the entire set.

Part B: Syntactic Variables

Subjects. Twelve graduate students at the University of Pennsylvania served as subjects. All were native speakers of English, and were paid for their participation. These subjects also participated in Part B of Experiment 2.

Stimuli. The sentences were created by placing each verb in each of the three frames that were used to make up the 3-NP variable. These frames are shown, along with examples, in Appendix A. The resulting 60 sentences were written to be as plausible as possible.

Procedure. The sentences were presented on rating sheets and rated for naturalness as in the previous experiments, with one group of six subjects rating one subset, and another six

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[19] To ensure that our choice of verbs had not followed some hidden semantic criterion that misrepresented the set of cognition verbs available in the language, we checked the list of words obtained against a word frequency chart. The same three criteria were used to select all the suitable verbs from the set of the (approximately) 500 most frequent English verbs as found in Carroll, Davies, and Richman (1971). The resulting list included virtually all of the verbs shown in Table 7, along with about 30 others, all very close semantic associates of the verbs in our list.

TABLE 7
Verbs for Experiment 4

3-NP verbs	2-NP verbs
explain	think
argue	know
claim	believe
suggest	wonder
promise	guess
insist	doubt
announce	understand
demand	imagine
confess	remember
admit	forget

rating the other. As in all previous experiments, all the sentences in a single frame were presented together.

Results and Discussion

As expected, we found that the cognition verbs could be divided on both semantic and syntactic grounds. The two divisions overlapped to a considerable degree and supported the transfer hypothesis. This was shown by two related analyses. One was the usual regression analysis predicting semantic similarity scores. The other was a post hoc "match-to-sample" analysis of the triad choices.

Procedural Checks: Reliability

The concordance between the similarity scores given by the two groups of subjects for this set of verbs is comparable to the match between subject groups found in previous experiments ($p < .001$ by Hubert's, 1979, method, Spearman's $\rho = .79$). As before, all subsequent analyses are based on averaged similarity scores obtained from the two groups. The scores for each verb on the syntactic variable 3-NP are given in Appendix B. These data show that the subjects agreed, on the whole, with our division of the verbs. All of the verbs that we had classified as accepting 3-NP frames received higher scores on the 3-NP variable than any of the ones we had not, with one exception: the verb *insist* was given quite a low score, and was therefore reclassified as a 2-NP verb for the purpose of the subsequent match-to-sample analysis.[20]

[20] This oddity appears to be a result of our choice of 3-NP frames to be used in this analysis. *Insist,* in our judgment, occurs in sentences such as *John insisted to Mary that the answer was right*. However, no three-argument sentences in which one argument was an embedded sentence were used in this experiment.

The reliability of these syntactic judgments was computed as in Experiments 1, 2, and 3 by computing the median Spearman correlation between pairs of subjects' ratings. The resulting median correlation between the judgments of 3-NP frames was a very respectable .67.

Comparison of Syntax and Semantics

In an overall regression analysis, the variable 3-NP significantly predicted the similarity scores ($p < .001$, $R = .43$). Thus, as in previous experiments, the syntactic property 3-NP is strongly related to the meaning of this group of verbs.

Post hoc triad analysis. To test the hypothesis that there is a substantial overlap between the semantic and syntactic distinctions within this group of verbs, we performed a further analysis of the triad data. We considered only two sets of triads. Set A was composed of triads in which there were two verbs that do and one verb that does not take 3-NP frames. Set B was composed of triads in which there were two verbs that do not and one verb that does take 3-NP frames. The hypothesis was that, other things being equal, the syntactically dissimilar verb should also be chosen as the semantic mismatch.

The definition of the two sets was based on the subjects' own acceptability judgments (with *insist* classified as a 2-NP rather than a 3-NP verb). This led to a total of 495 triads in Set A and 396 in Set B. We now calculated the proportion of trials on which the subjects regarded the syntactically odd verb (that is, a 2-NP verb in Set A, a 3-NP verb in Set B) as the semantically odd one. Since there were three verbs in each triad, any one of which could be chosen as the one that did not fit, the proportion expected by chance is .33. All 16 of the subjects in the triad task chose the syntactically odd verb in these triads on more than this chance proportion of trials. (A sign test shows 16 of 16 to be significantly more extreme than expected by chance, $p < .001$.) The mean proportion actually obtained was .61. This result allows us to conclude not only that the variable 3-NP is strongly related to the meaning of this set of cognition verbs, but also that the relationship holds true for every one of our individual subjects.

Cluster ANOVAs. The fact that substantially more than a chance proportion of the relevant triads were judged as predicted strongly suggests that the syntactic property of occurring with 3-NP frames is relevant to the meaning of these verbs. Thus, the first question posed in this experiment is answered in the affirmative.

To examine this finding more closely, the similarity data were submitted to a cluster analysis; we performed ANOVAs to assess the extent to which membership in each of the six resulting clusters was marked by scores on the 3-NP variable. The results of these analyses are summarized in Table 8. As the Table shows, clusters 1 and 2 reveal a near-perfect division of the verbs into those that take 3-NP frames and those that do not.

In this case, the syntactic/semantic correspondence is easy to interpret and label. Recall that in Experiments 1 and 2 a semantic factor that we have so far called transfer emerged from the triad procedure and was found to be associated with the syntactic variable 3-NP. The transfer property applied to certain verbs both within the class of cognition verbs (e.g., *argue* but not *think*) and outside this class (*take* but not *walk*). Our hypothesis was that transfer for motion (physical) verbs was interpretable as the motion of objects between places or persons; and that for mental (cognition) verbs, the same property was interpretable as the "motion" of thoughts between minds, i.e., communication. The present experiment examined this hypothesis, asking whether a clear distinction within the set of cognition verbs would reflect this syntactic difference, and whether the resulting semantic/syntactic classification of the verbs would fit our initial interpretation. The results supported the specific hypothesis that motivated Experiment 4: The 3-NP verbs are grouped together semantically and stand apart from the verbs that do not accept 3-NP frames (Table 8); and the resulting classification can be described as a distinction

TABLE 8
Clustering and ANOVA Results, Experiment 4

Clusters	Weight	3-NP
1. explain argue claim suggest promise insist announce demand confess admit	5.86	$F = 24.34^{***}$
2. think know believe wonder guess doubt understand imagine remember	4.53	$F = 11.42^{**,a}$
3. think believe wonder imagine	5.26	$F = 4.78^{*,a,b}$
4. argue claim insist demand	5.92	$F < 1$
5. announce confess admit	5.70	$F = 1.15$
6. know understand remember forget	5.02	$F = 2.06$

* $p < .05$.
** $p < .01$.
*** $p < .001$.
[a] The verbs in this group tend to have *lower* scores on the SubCat variable 3-NP than verbs not in this group.
[b] The membership of this semantic cluster was not found to be predictable in the corresponding discriminant analysis: the best discriminant function based on the variable 3-NP correctly placed only 80% of the verbs, no better than the 80% correctly placed simply based on the prior probabilities of group membership.

between verbs of communication (cluster 1, *explain, argue, claim, suggest* and so on) and verbs that describe states and acts within a single mind (cluster 2, *think, know, believe, wonder,* and so on).

Other semantic clusters. An examination of further semantic clusters, unrelated to the syntactic variable 3-NP, as usual reveals several additional properties of verb meaning. The verbs in cluster 4, *argue, claim, insist,* and *demand,* involve some fervor or conviction (related to Quirk, Greenbaum, Leech, & Svartvik's 1985, mandative verbs) when compared to the blander cases of simple communication in cluster 5 (*announce, confess,* and *admit*). Cluster 3 (*think, believe, wonder,* and *imagine*) contains verbs that do not presuppose the truth of the embedded proposition (e.g., *John thinks/wonders whether/imagines/believes the moon is made of green cheese,* related to Bresnan's, 1979, dubitative verbs).

Summary. In this experiment, we used the procedures developed in Experiments 1 and 2 to document an important local interpretation of the syntactic variable 3-NP: transfer, with cognitive verbs, expresses communication. The results also provide further support for our more general hypothesis: The correspondences between semantic and syntactic properties do more than mark divisions *between* broad semantic domains; the correspondence patterns also mark divisions *within* such domains.

EXPERIMENT 5

We have presented a number of specific cases of quite reliable syntactic/semantic correlations; that is, cases in which the clause structure licensed for a verb and features of its interpretation are copredictable. Such findings are in line with the positions of several linguists that we discussed in introductory remarks: The subcategorization frames are relatively straightforward projections from certain semantic features (Bresnan, 1979; Jackendoff, 1978; Chomsky, 1981).

A central question is whether these syntactic/semantic mappings can be recruited by the child, as *input* to language learning, that is, whether the syntactic distinctions can be used as clues to the semantics. For this to be so, it cannot be the case that all such mappings are language specific (for then the mystery of this part of language learning would not be solved, but only translated into the new mystery of how the child could acquire the mapping rules themselves). Rather, the child might come equipped with certain commitments about such rules, e.g., that every semantic role is assigned to one and only one argument position, that entities are encoded by NP's and activities by clauses, etc.[21] But then, for it to do the child any

[21] These examples are not so abstract or difficult as they might appear at first glance—rather they might be so self-evident as to be implicitly conjectured by any self-respecting tot without the need for "learning" in any traditional sense of that term. The first idea here

good to have hypotheses about how syntax maps onto semantics, *it must be the case that, regardless of the specific language to which the learner is exposed, that language exhibits the same (or virtually the same) syntactic/semantic relations.*

In the present experiment, we make a small beginning toward showing that the kind of result we have reported is reproduced in another language. Specifically, here we replicate Experiment 4 in Italian. As in English, there are Italian verbs of cognition that differ in whether they occur in 3-NP frames, so again we can ask whether this syntactic distinction maps onto some semantic division within the domain of Italian cognition verbs. Further, given a corresponding semantic division, we can ask whether our interpretation of this division for English holds true for Italian.[22]

Method

Part A: Semantic Similarity

Subjects. Sixteen subjects participated in the semantic triad task and were paid for their participation. Most of them were students at the University of Pennsylvania, a few were recruited from outside the University. All were native speakers of Italian, and, although all spoke some English, none were native speakers of English.

Stimuli. Twenty verbs formed the experimental set. The criteria for choosing the verbs were the same as in Experiment 4, as judged by an Italian informant: (a) all verbs accept at least one SComp frame, (b) they are cognition verbs on some reading, and (c) half of them accept 3-NP frames, while half do not. These rules were applied to a word-frequency list in order to ensure that no covert semantic criteria were used in choosing the verbs (Juillard & Traversa, 1973). The final list is shown in Table 9.

Procedure. The instructions and all the on-screen prompts for the triad task were translated into Italian; the experimenter (see footnote 22) spoke Italian to the subjects throughout the procedure. As in Experiment 4, each subject was shown 150 of the 1140 triads; two groups of eight subjects (two meta-subjects) completed the entire set of triads.

(roughly, the theta criterion and projection principle as discussed by Chomsky, 1981) is that an NP is required for each entity logically related to the semantics of the predicate, e.g., that *put* requires more NP's than *sleep,* as we discussed. The second idea is that NP's are likely to encode things, while whole clauses describe propositions; see Markman and Hutchinson (1984) for experimental evidence of such a bias in toddlers, and its explanatory role for vocabulary acquisition. Since cognition and perception verbs, then, describe relations between an agent and a proposition (*John believes that Sam is eating/ hears that Mary flunked calculus*), their appearance with SComps might be straightforwardly predictable.

[22] This experiment was carried out in collaboration with Raffaella Zanuttini, a linguist at the University of Pennsylvania, who constructed the stimulus list and found and ran the subjects. It should be obvious that the choice of Italian was not optimum for this experiment (because the language is one that is too closely related to English to support significant cross-linguistic generalization of the results). But we were constrained not only by the requirement to have a linguistically sophisticated speaker of another language for creation of the materials (that is, R.Z.), but also by the requirement to have a college-level native-speaking population of subjects in the language chosen.

TABLE 9
Verbs for Experiment 5

2-NP verbs	3-NP verbs
sapere (know)	dire (say)
pensare (think)	parlare (talk)
credere (believe)	chiedere (ask)
capire (understand)	avvertire (warn)
notare (indicate)	raccontare (tell)
desiderare (want)	spiegare (explain)
sperare (hope)	mostrare (demonstrate)
indovinare (guess)	ricordare (remember/remind)
dubitare (doubt)	promettere (promise)
intendere (mean)	insegnare (teach)

Part B: Syntactic Variables

This study differed from the English version in that all sentence judgments were made by one linguistically sophisticated Italian informant, rather than by a group of more linguistically naive college students. This was due to the difficulty of finding Italian subjects. The informant simply divided the verbs into two categories on the basis of her judgment of whether or not they appeared in 3-NP sentences, as shown in Table 9.

Results and Discussion

Just as in English, we found for the Italian items that the group of cognition verbs could be divided on both semantic and syntactic grounds. This was shown by a "match-to-sample" analysis like the one performed on the data from Experiment 4.

Procedural Checks: Reliability

The concordance between the semantic similarity matrices obtained from the two groups of subjects is comparable to the match between subject groups in the English version of this experiment ($p < .001$ by Hubert's, 1979, method; Spearman's $\rho = .72$). As previously, further analysis of these data were based on the averaged similarity scores.

Comparison of Syntax and Semantics

To test the hypothesis that there is a significant overlap between the semantic and syntactic divisions within this group of verbs, two critical sets of triads were examined. Set A was composed of triads in which there were two 3-NP verbs and one 2-NP verb; Set B was made up of triads containing two 2-NP verbs and one 3-NP verb. As in Experiment 4, the hypothesis was that, other things being equal, the syntactically dissimilar verbs should also be chosen as the semantic mismatch.

There were a total of 948 triads in Sets A and B. All 16 subjects chose the syntactic outlier as the semantic mismatch in more than a chance proportion of these triads (where chance is 1 of 3; 16 of 16 is more extreme than expected by chance by a sign test, $p < .001$). The mean proportion of congruent choices obtained was .50. This result exactly mirrors the findings in Experiment 5: The variable 3-NP is strongly related to the meaning of a set of Italian cognition verbs, and this relationship holds true for every subject.

Thus, we see that a syntactic variable, occurrence with 3-NP frames, which was previously found to map onto significant semantic distinctions among English verbs, behaves exactly the same way in Italian. An examination of the glosses provided in Table 9 shows that the semantic division so marked seems to be the same in Italian as in English: According to our informant, Italian verbs of cognition that occur in 3-NP frames are verbs of communication, or transfer in the cognitive domain, just as in English.

Summary

In Experiments 1, 2, and 4, an axis of semantic similarity, tentatively dubbed transfer, was found to be associated with the syntactic variable 3-NP. This relationship holds for English verbs of cognition (where transfer becomes communication, i.e., transfer of ideas across minds) as well as English motion verbs (where the transfer is of physical entities across space). The results of the present experiment, identical to Experiment 4 save for the switch from English to Italian, extend this conclusion to another (admittedly related) language. While this is only a first small step in exploring relations between verb syntax and semantics cross-linguistically, it represents the kind of result needed to build a case that the child can use the syntactic environments in which verbs occur as clues to their meanings. To repeat, this is because (a) the semantic/syntactic correspondences have to be reliably present in the language for the child to make use of them; but moreover (b) those linkages must be about the same from language to language if they are to serve as *input* to the verb–vocabulary learning procedure.

GENERAL DISCUSSION

The experiments reported here represent the first uses of a method that we believe will be useful in exploring the relationship between verb subcategorization and verb meaning. The results provided evidence of robust correlations between verb syntax and semantics. In all five experiments, verbs which (as the subjects told us in the triad task) are intimately related semantically are also (as other subjects told us by making judgments of sentence naturalness) related in their syntax. Specifically, our findings are consistent with claims in the linguistic literature that:

1. Spatial verbs are associated with PP frames.
2. Mental verbs are associated with SComp's.
3. There is a local interpretation of this association for the special case of perception verbs (attempted versus achieved perception, related to but not identical with the active/stative distinction drawn by linguists).
4. Transfer verbs are associated with 3-NP frames.
5. Mental transfer (or communication) verbs are associated with both 3-NP and SComp.

Thus, the procedure has delivered on some of its promises for extracting relationships between syntactic and semantic structure. As we acknowledged in beginning, the outcomes in these first experiments in large part simply support prior linguistic findings rather than mining new semantic/syntactic territory in the lexicon. Our main purpose here was to validate the procedures themselves, for we think that these, with suitable choices of the verb sets compared, can support a refined examination of the verb–lexical organization. In contrast, the known complexity of this organization makes it unlikely (in our view) that informal methods will be sufficient to this task. We turn now to a closer consideration of organization in the verb lexicon.

A Schema for the Verb Lexicon

This is no place to present a formal picture of the mental lexicon, nor are we ideally positioned to offer such a formalism. What we will present is an informal sketch of the kind of organization that seems reasonable to us, given our initial results and many related results from linguists and psychologists whom we have cited.

The claim we have been defending is that a relatively small number of abstract semantic elements, such as transfer, are encoded on the SubCat frames rather than (or in addition to) appearing in the lexicon as item-specific information associated with individual verbs. These frames will be chosen for utterance with particular verbs, depending on whether all aspects of the meanings of those verbs are compatible with the meaning, or truth-conditions, of the frame itself. Thus, to whatever extent the notion of transfer is incompatible with some aspect of the meaning of, say, *laugh* (e.g., with the "ho-ho" part of that meaning), then *laugh* will not be heard in 3-NP structures.

Since verbs accept several such semantically relevant SubCat frames, in effect the frame set for a verb cross-categorizes that verb in such a way as to define potentially quite small and refined semantic groups. For example, there are several hundred verbs of cognition and perception, and these are generally compatible with SComps, for they describe relations between an agent and a proposition. And there are hundreds if not thousands of verbs that express transfer of possession and thus are compatible with 3-NP structures. But there are many fewer verbs which express *both* these semantic properties and which therefore are compatible with both SubCat frames; specifically, these two syntactic clues, associated with some new verb, strongly predict that it is a verb of communication: As Zwicky told us (see the opening quotation to this paper), knowing that *greem* is a verb of communication is enough to predict these two frame types. By the same token, these syntactic properties are enough to predict that *greem* is a verb of communication. By hypothesis, then, the child inspecting the licensed surface structures can gain significant evidence about the verb meaning.

An extreme version of this componential mapping scheme is that each SubCat frame encodes a single verb–semantic element, each such element has a frame assigned to it, and thus the set of frames for a verb predicts, or corresponds to, the full predicate meaning. In that case examination of the full range of SubCat frames for a verb would provide a direct and complete discovery procedure for its meaning. Even on a conservative estimate of the number of these SubCat frames available in a language, there are enough of them to support a very strong view of how syntax might encode lexical semantics. Assuming that there are 100 SubCat frames, and that a verb can choose between 1 and all 100 such frames, there are 2^{100} possibilities. This number is awesomely larger than the number of monomorphemic verbs that any language has or could have. That is, there is plenty of room in such a scheme for the meaning distinctions among the verbs to be fully encoded as the distinctions in their range of frames (see Zellig Harris, 1951, for seminal discussion). The extent to which a language truly recruits this formal resource for semantic purposes has been the question under consideration in this investigation.

However, there are many reasons to suspect that languages do not exploit this formal resource in so refined a way as just described. Foremost among these is the requirement for the syntactic/semantic linkages to be "cognitively transparent," for structures to be assigned to verbs not on some stipulative basis, but rather in a way that is consistent with the meaning to be conveyed. As instances we have mentioned, participants in the action described by the verb should be mapped one-to-one onto NP's in its clause structure; relations of different kinds among the participants should be coded in different ways, e.g., between experiencers and objects by NP's (e.g., *John* saw *a mouse*) but between experiencers and events by clauses (e.g., *John* saw *that Bill was spilling the juice*). This necessity, if real, of the clause structures to convey the verb logic in a certain way—rather than any old way—radically reduces the space available in the hypothetical verb/frame matrix. We should expect, given this severe limitation, that the SubCat space can provide only a relatively coarse semantic partitioning of the verbs. If this partitioning is finer grained, it is only because the verb/frame matrix in real languages is so sparsely populated that the range of frames for a verb can be closely informative of its meaning.

Another reason for supposing that only a subset of semantic properties is syntactically encoded comes from the findings we have presented. In each of the experiments presented we found semantic clusters of verbs which were unrelated to any of the syntactic distinctions under consideration, but which were nevertheless interpretable as representing aspects of verb meaning. Most notably, the triad (semantic judgment) results of both Experiments 2 and 3 yielded several clusters clearly based on perceptual modality and manner. These undoubtedly semantic properties had no direct reflection in the syntactic properties examined here. Of course it may be that these semantic properties do have syntactic correlates that we did not happen to examine experimentally. But the conjecture that they are not reflected in the SubCat structure is bolstered by results from inquiries into how such aspects of verb meaning are acquired.

We take as an example the idea (based on the findings of Experiment 3) that there are no SubCat variables devoted to particular sense modalities, i.e., that vision verbs and audition verbs do not appear in different SubCat structures due to the difference in the modalities they describe. This idea is consistent with the findings of Landau and Gleitman (1985): They studied the acquisition of visual verbs by sighted and by blind children and demonstrated (with comprehension experiments) that both groups by age 3 years, in spite of obvious differences in their extralinguistic observations, understood that *look* and *see* describe perception and differ from each other in that *look* is active (or exploratory) and *see* is stative (or achievement).

Landau and Gleitman hypothesized that it is the verbs' syntactic properties, exhibited in the caretakers' speech, that allowed these inferences to be made, i.e., that the children were attentive to the structures in which the meaningfully distinctive verbs occurred and used this structural information as clues to the interpretations of those verbs. To the extent that this is so, the difference in observational circumstances of the two groups was redressed by sameness in their linguistic circumstances.[23]

[23] Specifically, the caretakers used *look* and *see* but not verbs of physical contact or motion, such as *touch* or *bring*, with SComps. This association between verbs of perception/cognition and SComp structures is probably universal. Landau and Gleitman hypothesized that it served the learning needs of both the blind and the sighted children, leading them all to the supposition that *look* and *see* were perception verbs (as shown by various comprehension tests). Similarly, since the caretakers used *look* and not *see* in the syntactic envi-

However, blind and sighted children in these studies differed in one aspect of their construal of the verbs *look* and *see*. Blind children behaved as though these verbs pertain to haptic exploration and perception, while, obviously, sighted children believe these verbs to pertain to visual perception. For example, in response to the command "Look up!" blindfolded sighted toddlers turn their covered eyes skyward, while blind toddlers keep their heads immobile but search the air above them with their hands. This finding is exactly as would be expected if the meaning component "visual" is never encoded in the syntax of these verbs (which is observable to both the blind and the sighted children), but rather is learned from extralinguistic observation alone (which varies relevantly for the blind and sighted children).

Constraints on the Syntactic/Semantic Mappings

We have just considered three kinds of argument suggesting that the syntax only *partially* partitions the verb set semantically: The mapping relations have to be conceptually coherent ("transparent") if they are to be of use to an acquisition procedure; semantic structure obtained from the triad studies, submitted to cluster analysis, was much richer than that part of it associated with known syntactic variables; and the semantic information provided to the child learner by distinctiveness of the SubCat range is helpful, but insufficient, as a basis for acquiring all semantic generalizations.

On the hypothesis that only some semantic properties are encoded in the syntax, we now want to ask what kinds of properties these are likely to be. We propose that three related distinctions constrain the possible syntax/semantics correspondences and conspire to explain why some semantic properties are marked in the syntax while others are not:

1. The formalism of subcategorization allows only the representation of argument-taking properties of the verb.
2. On grounds of representational efficiency, the semantic properties represented in the SubCat structures should be very general ones.
3. Semantic properties that are closed to observation must be marked in the syntax if the language learner is ever to discover which words in the language express them.

As we shall see, all these constraints seem to be related to the logical problem of learning the meanings of new words: Language is as it is owing to the necessity of being learnable by children.

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ronments appropriate to so-called active and not stative verbs (progressive and imperative structures), even the blind children understood this distinction for these two verbs.

Argument-Taking Properties of the Verb

The formal medium of subcategorized phrases constrains the semantic content that it is capable of expressing. Since the subcategorization properties of verbs are the syntactic expressions of their arguments, it is only those aspects of a verb's meaning that have consequences for its argument structure that *could* be represented in SubCat frames. Specifically, these frames differ in the number, arrangement, and marking of argument positions. Properties of semantics that do not involve such distinctions do not affect SubCat structures.

As a case in point, consider Fillmore's discussion of manner, as exemplified by the difference (roughly of rate and energy) between the verbs *run, skip,* and *walk* or by the difference in kind of destruction between *break* and *tear* (Fillmore, 1968). He pointed out that such differences appear to have no formal reflection in the structure of clauses in English.[24] Take the distinction between *slide* and *roll*. This has no effect on the number or type of arguments the verbs will take: Both verbs require (a) the specification of an object that undergoes the motion and allow (b) the specification of the path along which the motion proceeds and (c) an external agent that causes the motion. Thus both fit in formally identical structures:

(25) *The car slid/rolled (down the hill).*

(26) *Bill slid/rolled the car (down the hill).*

Though the facts are more complex by far, many of the same generalizations apply to the verbs studied in Experiment 3, which pertain to perception in different sense modalities. All of these verbs require (a) specification of the entity that perceives and allow (b) specification of the entity perceived or (c) of the event perceived.[25] Thus *see* and *hear* appear in many of the same frames although they differ in the sense modality whose operations and outputs they describe, e.g.,

(27) *John saw/heard the train.*

(28) *John saw/heard that the train was wrecked.*

[24] There is at least one caveat to this proposed generalization. Whether a verb expresses a manner (*whisper*) or does not (e.g., *tell*) does seem to have syntactic consequences. The item not marked for manner of communication occurs in the double-object construction, while very similar manner verbs do not (compare, e.g., *John told Mary a story* and *?John shouted Mary a story;* see Zwicky, 1971, for a discussion of such facts). Levin (1985) and Pinker (1987) list other cases in which verbs that specify manner differ in syntactic properties from verbs encoding a very similar relation between arguments without specifying manner. This, however, is a semantic distinction of a different kind than the one we have in mind: specifying +manner/−manner is different from *particular* manner specifications for such verbs as *roll* or *slide*.

[25] One of several complications is that the chemical senses are not treated as though one can perceive events by their use, so they are probably odd with sentential complements.

We can see, then, that SubCat information is limited as a medium for expressing meaning: Its only elements are the type and position of a verb's subcategorized arguments. Given this, it is only the meaning of a verb as an argument-taking predicate that can be represented by this formal device (See Rappaport, Levin, & Laughren, 1987, for a similar argument).[26]

Feature Generality

The kinds of semantic features that have syntactic correlates appear to be distributed broadly across the lexicon: Notions such as "spatial" and "transfer" do not apply only within a narrow topic area (or semantic domain) but seem to apply across many domains. As we have discussed, both objects and—at least metaphorically—ideas can be transferred, so the property of transfer shows up both in verbs of physical motion and in verbs of communication. Similarly, such notions as "cause" and "mental" versus "physical" are broadly applicable over the verb set.

If parsimony or efficiency of representation are at all relevant to the psychological organization of the verb lexicon, we would expect just such general semantic features as these to be syntactically encoded. For if such pervasive features had to be indicated separately for each of the verbs to which they can apply, they would necessarily appear in hundreds, even thousands, of verb entries. Furthermore, a great many verbs would then require disjunctive (or multiple) definitions, for the same verbs appear in different constructions with correspondingly different interpretations. For example, *move, sink, bake, burn, open,* etc., would have to be spec-

[26] One might well wonder why we have limited the discussion to subcategorization, for other information that is structurally encoded is relevant to interpretation. For instance, adverbs and adjunct phrases of various kinds also tend to differ in their distribution across verbs, as Gruber (1967) pointed out, and are relevant to semantic distinctions such as active/stative (compare *John looked/*saw surreptitiously through the window, Bill looked at/*saw the answers to the test in order to get a passing grade*). Landau and Gleitman (1985) and Rispoli (in press) suggest that language learners could use this kind of evidence to infer semantic classification of verbs. However, it is the meanings of some adverbs, not adverbs as a syntactic class, that are doing the work here (e.g., both *John looked at/saw the answer briefly* are acceptable). And there are good reasons to restrict the learning procedure in such a way that it will not seize upon any and every potential piece of information (such as the distribution of some but not all adverbs) as a source of data lest, in the urge to take everything into account, the procedure become choked with data and thus unable to learn anything at all. Such arguments are familiar to those who worry about "poverty of the stimulus information" (e.g., Chomsky, 1957, 1986) and, as the opposite side of this coin, "the latitude of the hypothesis space" (e.g., Quine, 1960; Chomsky, 1957, 1986). On such considerations, Landau and Gleitman asked whether an effective learning procedure for verbs could be developed whose data were only (a) the SubCat frames, (b) knowledge of noun referents, and (c) an extremely impoverished and constrained observational database.

ified as "plus or minus cause" (or be regularly polysemous), *depending directly on whether they occurred in intransitive or transitive syntactic environments: Open* is noncausative in *The door opens* but causative in *John opens the door.* An efficient alternative, one that we think human languages exploit, is to render these very general semantic properties by assigning truth conditions to syntactic structures.

We admit that such arguments from efficiency are more compelling for small-brained computers than for human brains of unknown capacity. But whether or not it is relevant to issues of human information processing capacity, we believe that the notion of efficiency (or limited capacity) may at least serve as a heuristic for predicting which semantic elements will and will not be marked on the surface of sentences.

Learnability: Semantic Elements Closed to Observation

On the hypothesis that there are pervasive correspondences between the syntax and semantics of verbs, it is in principle possible to predict aspects of the meanings of verb items from their syntactic behavior. The usefulness of such a form-to-meaning procedure is fairly obvious, once the problems of a learning theory that operates directly (and solely) from extralinguistic observation are faced. One such problem has to do with the "stimulus free" character of even language use that is (in some way) pertinent to ongoing events: There seems no end of pertinent things one could say, given some observed situation. So how is the child to guess which of these alternatives is encoded in the utterance that accompanies the observation? This problem reaches its limits for words which describe the same scenes or events from different perspectives, or at different levels of generality. For example, whenever *John drops a ball,* the ball *falls,* and John never *sees* that the door is open without *perceiving* that it is open. And there is no *running* without *moving, chasing* without *fleeing, placing* without *putting, buying* without *selling, taking* without *getting,* or *winning* without *besting* or *beating.*

How are the distinctions between these pairs of verbs to be acquired if they are used always and only to describe the same events? If the child understands the referents of nouns used in a sentence, and also understands the syntax/semantics mappings, there is a solution: The child can examine the SubCat frames. A number of experiments now document that young learners are attentive to this structural information and use it to deduce the meanings of new words. For instance, Naigles (in press) showed 24-month-old children videotaped scenes in which a rabbit was with his left hand forcing a duck to squat while, simultaneously, both rabbit and duck wheeled their right arms wildly. Some children were introduced to this scene as *The rabbit and the duck are gorping* while others were introduced with *The rabbit is gorping the duck.* When two videos, dissociating these two scenes, were then shown and identified as *gorping,* the children looked at different screens as a function of the syntactic introducing circumstances: Those introduced to the transitive structure looked at the causal scene (of a rabbit forcing a duck to squat), while those introduced to the intransitive structure looked at the non-causal scene (of a rabbit and a duck wheeling their arms (Naigles, in press); for further documentation of such effects, see Naigles, Gleitman, & Gleitman, in press; Fisher et al., forthcoming).

Our hypothesis, then, is that semantic properties whose instances are closed to observation are among those which are exhibited in the clause structure. Specifically, distinctions that have to do with varying perspectives on exactly the same scenes (temporal succession vs causation), attempted vs achieved perception, etc.) could never be distinguished by direct observation: Metaphors aside, one must look if one is to see, and therefore there will be no observed scenes referred to as "scenes of seeing" which cannot be construed just as well as "scenes of looking." These unobservable distinctions, as they map onto verb items, are nevertheless acquired by young children. Since this acquisition does not occur by magic, there must be *some* kind of data which reveals them. Our hypothesis is that the varying SubCat structures provide the required database for assigning these abstract semantic properties to certain verbs.

In contrast, many semantic properties whose instances are readily observable in the real world do not seem to have syntactic reflexes—for example, the distinctions in manner and modality we discussed earlier. These components of the verb meanings may well be learned by observation of their extralinguistic contingencies. This would account for why the blind child who is handed a ball and told "Look at this ball," explores it with her hands and says "I see."

Constraints on Syntactic Encoding: Summary

We have described three related distinctions between components of meaning that suggest both principled and practical limits on the possible mappings between form and meaning. To recapitulate: the medium of SubCat frames allows only argument-taking properties of verb meanings to be represented in the syntax; considerations of representational efficiency suggest that only fairly general semantic properties will rate a correlated syntactic device; and considerations of learnability tell us that meaning components that cannot be discovered from extralinguistic observation must be deduced from the syntax.

That these three potential constraints on form/meaning mappings will often coincide in their predictions is clear from the examples discussed throughout: Particular specifications of manner, such as the difference in motion between *slide* and *roll,* have no consequences for argument structure, are unlikely to be widely useful throughout the lexicon, and seem likely to be easily observable from events in the world. A semantic property like cause, on the other hand, does affect specifications of argument roles (an agent must be present), is clearly applicable in many areas of the lexicon, and poses a classic problem for purely observational accounts of word learning (Hume, 1738/1962). Together, these three ways of classifying components of meaning may provide a device for directing experimental inquiry and offer the beginnings of an explanation for the distribution of syntax–semantics mappings in the verbal lexicon.

Language Use, Judgment, and Innovation

The notion that there are two kinds of elements of verb meaning—some correlated with syntactic properties, the other not—has some direct consequences for a theory of lexical organization. Our hypothesis is that the meaning of verbs in sentences is parcelled out (sometimes redundantly) between the clausal structure and the lexicon. To return to an example we mentioned earlier, the item-specific facts about the meaning of *laugh*—the mirthful explosion of air—would be represented individually as lexical-semantic information. Such properties of meaning encoded by the verb item can be augmented by the clausal structure in which the verb appears. To the extent that this is true, any verb can appear in any clause structure, and the final meaning will be a function of both the frame and the verb. A similar picture of verb meaning, in which parts of a verb's meaning are parcelled out in this way, is suggested by Carlson and Tanenhaus (1988) and Stowe (1987).

Why, then, do some verbs appear to be less acceptable than others—or more "metaphorical" than others—in certain syntactic environments? By hypothesis, it is because the naturalness of a particular structure is a consequence of the *interaction* between the several item-specific aspects of the verb's meaning (e.g., ho–ho) and the truth conditions of the structure (e.g., +cause). Insofar as laughing is an inalienable act directly caused by physiological adjustments within the body,

(29) *Horace laughed Mary.*

taken to mean "Horace made Mary laugh" is unacceptable: Mary herself must be the *direct* causal agent, if you will, of her own laughing. Note that indirect causation is expressed in English by the paraphrastic locution

(30) *Horace made Mary laugh.*

an unexceptional usage implying, say, tickling, a good joke, or scorn of Horace by Mary.

But is sentence (29) ungrammatical in the same sense as:

(31) **House the is red.*
**Who did you see my brother and?*
**Who did Horace believe the claim that Mary met?*

In our view, the violations we are discussing are quite different from those in (31) and derive from different organizational principles in the grammar of a language. The transitive structure of (29) is indeed ungrammatical for *laugh* but this structure fails for semantic and logical reasons: The frame implies direct causation of Mary's laughing by Horace but, to the extent that Mary is an independent entity whose laughing is necessarily self-caused, Horace cannot directly cause it. It should follow that if we reduce the independent status of the entity in Mary's sentential position, the ungrammaticality will go away, and of course it does. Compare (29) with

(32) *Gepetto danced Pinnochio.*

which is suitable before but not after Pinnochio becomes a real boy. (This may also be why you can lead a horse to water but you can't drink him.) In contrast, the examples in (31) fail on such formal grounds as violations of head-direction, subjacency, and so forth, properties that do not—like the SubCat properties—interact with lexical semantics.

If this general position is correct, we can also account for the fact that it is surprisingly difficult to get reliable SubCat judgments from linguistically naive subjects. For example, we just now confidently claimed that *laugh* in (29) is ungrammatical, while in fact real subjects waffle on such judgments. (This is why, in the present experiments, we were forced to provide a 5-point scale for judgments of grammaticality rather than asking for simple yes/no decisions.) If, as we propose, the SubCat frame contributes its truth conditions to the meaning of the verb in a sentence, then accepting or rejecting a sentence like (29) is just a matter of how far the subject will go in extending the sense of *laugh* so that it jibes with the syntactic requirements of the frame. Subjects differ in their tolerance here, and so pooling their judgments yields an intermediate degree of acceptability for such sentences.

In order to exclude such intermediate judgments for very unusual or metaphorical usages, we considered only syntactic variables for which we could get a reasonable degree of agreement among subjects. But in the light of the present discussion, we can make some sense of frame variables that produced *unreliable* judgments. Consider the sentence frames that made up the variable IPP (imperative, progressive, and pseudo-cleft sentences) in Experiment 1, which we had to drop from further analysis because they never produced reliable judgments. If such judgments of naturalness, while structural (that is to say, syntactic), are affected by semantic considerations, then their variability is not too surprising. The meaning of the syntactic structures that comprise the IPP variable is generally held to be such that only verbs that denote acts can occur in them (see, e.g., Vendler, 1967, but see also Dowty, 1975). Thus,

(33) *John is looking at the moon.*

is obviously acceptable, while

(34) ?*John is seeing the moon.*

is questionable. The verb *see* does not ordinarily accept the IPP structure, but the adjustment that is needed to bring *see* and IPP into alignment is relatively small: *seeing the moon* has to become an ongoing activity, perhaps something that John does for a living.

This perspective allows us to understand certain syntactic innovations and their regular semantic effects: While *laugh* is usually intransitive and noncausal due to its base meaning, it can sometimes be understood as causal and, if so, as transitive. *Horace laughed Mary* is certainly odd but, if it occurs, it must mean that Horace caused Mary to laugh. Young children frequently use novel SubCat frames to extend the meanings of known verbs beyond the contexts in which they have heard them in just this way (Bowerman, 1982); and both children and adults understand known verbs to take on new components of meaning when they hear them uttered in novel SubCat frames, as we previously discussed.

To sum up, the SubCat frames in which individual verbs are usually heard are a consequence of several properties of their meaning. Hence the characteristic SubCat privileges of verbs provide indirect clues to their overall meanings, as well as more direct information about their meanings in the relevant sentences. That these mappings exist and are part of linguistic knowledge provide an explanation for how old verbs in new SubCat environments can be understood. There seems no way to account for these consistent creations and interpretations if the SubCat privileges of verbs are simply stipulative. Imperfect as they may be, the relations between the verb meanings and the clause structures are known to ordinary language users and can be put to productive use.

Summary and General Conclusions

The experiments described here were presented as a demonstration, first, of the usefulness of a new method for examining the structure of a lexicon and, second, of the existence of a number of strong and reliable mappings between the syntax and semantics of verbs. In Experiments 1 and 2, we showed that the triad method could be used to reveal correspondences between structure and meaning in some fairly obvious places already discussed in the linguistic literature; Experiment 5 was a preliminary replication in Italian. In Experiments 3 and 4, we extended and refined these findings, showing that the method proposed is fine-tuned enough to uncover syntactic correlates of subtle distinctions in meaning within broad semantic classes. Although the substantive findings largely reproduce generalizations first discussed by the philosophers and linguists we have cited, the method begins to put some of the tangled questions about syntax/semantic correspondences on a different and more objective footing.

The findings suggest a view of the lexicon in which verb meaning and subcategorization facts are very closely intertwined. In cases where the meaning of the verb depends in part on the sentence in which it occurs, it is possible that the relevant aspects of meaning could be computed for each use rather than being recorded in the lexicon. Indeed, we know from findings concerning linguistic innovation that such on-the-spot computation can occur. But among the psycholinguistic performances for which this approach seems most promising, the child's deduction of word meanings from inspection of the semantic/syntactic correlations is the one we want to greem about most loudly.

APPENDIX A

Sentence Frames with Examples

Frame	Example
Prepositional phrase frames (PP)	
[to NP]	My friend walked to the movies.
[in NP]	The landlord stood in the doorway.
[on NP]	The traveler remained on the train.
[over NP]	The ball slid over the edge.
[at NP]	The boss remained at the store.
[for NP]	The fighter listened for the bell.
[across NP]	The ball slid across the sidewalk.
[toward NP]	The dog walked toward the cat.
[from NP]	Emily looked from the doorway.
[through NP]	The coin slid through the crack.
[between NP & NP]	The spy looked between the car and the house.
[under NP]	The woman stood under an umbrella.
[beside NP]	The teacher looked beside the desk.
[against NP]	The ladder balanced against the house.
[with NP]	The orphan remained with his aunt.
[by NP]	The princess lived by the sea.
[about NP]	Eddy knew about the accident.
Sentential complement frames (SComp)	
[that S]	Jane explained that her arm was broken.
[if S?]	Did you know if the train had arrived?
[whether S?]	Did you see whether your mother was home?
[NP VP_{inf} (bare)]	I saw my mother leave the house.
[NP VP_{inf}]	He believed the woman to be a spy.
[S]	She saw the door was open.
[NP_{poss} V-ing]	Alice explained her leaving an hour early.
Three-NP frames (3-NP)[b]	
[NP with NP][a]	The carpenter joined the leg with the table.
[NP from NP]	Mary took the book from her brother.
[NP to NP]	The boy saw his friend to the door.
[NP NP]	John slid the dog a bone.
Intransitive frames [ICon][a]	
NP & NP V []	The sofa and the chairs matched.
NP V []	The snowbank slid.

APPENDIX A—*Continued*

Frame	Example
Imperative, progressive and pseudo-cleft frames (IPP)[a]	
imperative	Look at the lion!
progressive	My sister is marrying a lawyer.
pseudo-cleft	What John did was to walk in the snow.

[a] These frames were stimuli for Experiment 1 only.

[b] Note that three of the 3-NP frames are also members of the PP set. The fact that one variable in our analyses (for Experiments 1 and 2) was virtually a subset of another one made no difference to any analysis, since regression analyses carried out with the shared frame excluded from the PP variable produced equivalent results.

APPENDIX B

Acceptibility Scores: Mean of All Subjects' Standardized Ratings for a Class of Frames

Verb	PP	SComp	3-NP
Experiment 1			
look	.444	−.640	−1.045
see	.137	.637	.515
listen	.462	−.690	−.768
hear	−.123	.599	.105
think	−.022	.051	−.270
know	−.477	.609	−.258
explain	−.064	.174	.755
believe	−.626	.290	−.043
walk	.981	−.506	.523
slide	.650	−.630	.700
give	−.061	−.910	.655
take	−.334	−.554	1.280
stand	.444	−.879	−.470
balance	−.077	−.957	−.365
remain	.412	−.960	−1.080
live	.249	−1.059	−.490
meet	−.426	−.730	.110
marry	−.178	−.851	−.215
match	−.593	−.877	.165
equal	−.489	−1.019	−.960
tie	−.346	−.954	.528
collide	−.328	−.990	−.743
argue	.498	.331	.313
join	−.338	−.841	.010
Mean	−.008	−.473	−.044
SD	.437	.592	.631

APPENDIX B—*Continued*

Verb	PP	SComp	3-NP
Experiment 2			
touch	−.406	−.889	−.590
feel	.296	.500	−.760
observe	.034	.819	−.313
glance	.366	−.716	−1.040
understand	−.593	.727	−.750
guess	−.063	.591	−.220
remember	−.064	.911	−.133
suggest	−.559	.514	−.137
crawl	.819	−1.011	−.867
run	1.122	−.711	.267
throw	.367	−.969	1.223
jump	.815	−.984	−.757
rest	.380	−.896	−.927
stay	.476	−.910	−.850
wait	.374	−.741	−.880
sit	.559	−.826	−.940
cut	.357	−.711	.580
attach	−.283	−1.039	−.167
fight	.857	−.433	.083
separate	−.539	−.873	−.263
Mean	.216	−.382	−.372
SD	.509	.729	.587
Experiment 3			
explore	.463	−.618	
examine	−.177	−.450	
perceive	−.613	.518	
sense	−.838	.852	
look	1.121	−.713	
listen	.440	−.623	
taste	−.626	.120	
smell	.024	.905	
touch	−.502	−1.008	
see	.192	1.172	
hear	−.208	1.193	
feel	.443	1.008	
gaze	.611	−1.098	
glance	.852	−.937	
peer	.776	−1.148	
peek	.746	−.925	
savor	−.884	−.737	
sip	−.188	−1.005	
sniff	.705	−.467	
finger	−.375	−.943	
handle	−1.020	−1.065	

APPENDIX B—*Continued*

Verb	PP	SComp	3-NP
glimpse	−.087	−.315	
sight	−.224	−.352	
scent	−.705	−.820	
Mean	−.003	−.311	
SD	.626	.801	

Verb	3-NP
Experiment 4	
think	−3.170
know	−1.120
believe	−1.950
wonder	−2.840
guess	−1.540
doubt	−2.970
understand	−2.470
imagine	−2.440
remember	−1.930
forget	−3.280
explain	.880
argue	.430
claim	−.660
suggest	−.590
promise	1.930
insist	−2.780
announce	−.100
demand	.020
confess	−.350
admit	−.460
Mean	−1.270
SD	1.490

APPENDIX C

Sentence Frames for Experiment 4

Frame	Example
Prepositional phrase frames (PP)	
[from NP]	The spy glanced from the roof.
[around NP]	The teacher glanced around the classroom.
[across NP]	The professor peered across his desk.
[between NP & NP]	The man felt between the sofa and the wall.
[under NP]	The child looked under the unmade bed.
[over NP]	The spy looked over the edge of the pit.

APPENDIX C—*Continued*

Frame	Example
[beside NP]	The driver glanced beside his car.
[through NP]	The witness heard through the door.
[for NP]	The soldier felt for his loaded gun.
[at NP]	The witch looked at her cat.
[toward NP]	The captain looked toward the island.
[to NP]	The girl explored to the top of the hill.
Sentential complement frames (SComp)	
[that S]	Susan heard that the party was boring.
[S]	Susan sensed the clouds were gathering.
[if S?]	Did you sense if the lock had been forced?
[whether S?]	Did you see whether the window was broken?
[NP VP_{inf} (bare)]	The hiker saw the sun rise over the hill.
[NP VP]	The spy glimpsed him delivering the note.

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