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Hard Words

Lila R. Gleitman
Department of Psychology and
Institute for Research in Cognitive Science
University of Pennsylvania, and
Center for Cognitive Science
Rutgers University

Kimberly Cassidy
Department of Psychology
Bryn Mawr College

Rebecca Nappa
Anna Papafragou
John C. Trueswell
Department of Psychology and
Institute for Research in Cognitive Science
University of Pennsylvania

How do children acquire the meaning of words? And why are words such as *know* harder for learners to acquire than words such as *dog* or *jump*? We suggest that the chief limiting factor in acquiring the vocabulary of natural languages consists not in overcoming conceptual difficulties with abstract word meanings but rather in mapping these meanings onto their corresponding lexical forms. This opening premise of our position, while controversial, is shared with some prior approaches. The present discussion moves forward from there to a detailed proposal for how the mapping problem for the lexicon is solved, as well as a presentation of experimental findings that support this account. We describe an overlapping series of steps through which novices move in representing the lexical forms and phrase structures of the exposure language, a probabilistic multiple-cue learning process known as *syntactic bootstrapping*. The machinery is set in motion by *word-to-world pairing*, a procedure available to novices from the

Requests for reprints should be sent to Lila R. Gleitman, Department of Psychology, Suite 302C, 3401 Walnut Street, University of Pennsylvania, Philadelphia, PA 19104–6228. E-mail: gleitman@psych.upenn.edu

onset, one that is efficient for a stock of lexical items (mostly nouns) that express concrete basic-level concepts. Armed with this foundational stock of "easy" words, learners achieve further lexical knowledge by an arm-over-arm process in which successively more sophisticated representations of linguistic structure are built. Lexical learning can thereby proceed by adding *structure-to-world mapping* methods to the earlier available machinery, enabling efficient learning of abstract items—the "hard" words. Thus acquisition of the lexicon and the clause-level syntax are interlocked throughout their course, rather than being distinct and separable parts of language learning. We concentrate detailed attention on two main questions. The first is how syntactic information, seemingly so limited, can affect word learning so pervasively. The second is how multiple sources of information converge to solve lexical learning problems for two types of verbs that pose principled obstacles for word-to-world mapping procedures. These types are perspective verbs (e.g., *chase* and *flee*) and credal verbs (e.g., *think* and *know*). As we discuss in closing, the outcome of the hypothesized learning procedure is a highly lexicalized grammar whose usefulness does not end with successful acquisition of the lexicon. Rather, these detailed and highly structured lexical representations serve the purposes of the incremental multiple-cue processing machinery by which people produce speech and parse the speech that they hear.

> You can observe a lot just by watching.
> —Yogi Berra

Much of linguistic theory in the modern era takes as its central task to provide an account of the acquisition of language: What kind of machine in its initial state, supplied with what kinds of input, could acquire a natural language in the way that infants of our species do? Chomsky (1980) cast this problem in terms of the "poverty of the stimulus," or Plato's Problem. What is meant here is that if input information is insufficient to account for the rapidity, relative errorlessness, and uniformity of language growth, it follows that certain properties of language—alternatively, certain ways of taking in, manipulating, and representing linguistic input—are preprogrammed in human nature. Usually, linguists are talking about the acquisition of phonology (e.g., Dresher, 1998) or syntax (e.g., Hornstein & Lightfoot, 1981; Pinker, 1984) in this context. Not vocabulary. For this latter aspect of language, the poverty of the stimulus argument is hardly raised, and it is easy to see why. With rare exceptions, everybody seems to subscribe to something like Yogi Berra's theory, as tailored to vocabulary growth in particular: One acquires the meanings of words by observing the contingencies for their use—that is, by pairing the words to the world. For instance, we learn that "cat" means 'cat' because this is the word that is uttered most systematically in the presence of cats and the least systematically in their absence.[1] All the learner has to do is match the real-world environment (recurrent cat situations) with the

[1]Notationally, we use *italics* for mention of a phrase or word, "double quotes" for its utterance or sound, and 'single quotes' for a concept.

sounds of the words (recurrent phonetic sequences) in the exposure language. Here is an even more famous version of this theory, from John Locke:

> (1) If we will observe how children learn languages, we shall find that … people ordinarily show them the thing whereof they would have them have the idea, and then repeat to them the name that stands for it, as 'white,' 'sweet', 'milk', 'sugar', 'cat', 'dog'. (1690/1967, 3.9.9)

The British Empiricists were of course cannier than this out-of-context passage implies and evidently only meant to make a start with this word-to-world pairing procedure (afterward, *reflection* and *imagination* would take over). Notice, in this regard, that to make his story plausible, Locke has selected some rather transparent examples, items for which perception might straightforwardly offer up the appropriate representations to match to the sounds. If there is a cat out there, or whiteness, this may well trigger a "salient" perceptual experience. But what of such words as *fair* (as in "That's not fair!"), a notion and vocabulary item that every child with a sibling learns quickly, and in self-defense? Or how about *know* or *probably*? How does one "watch" or "observe" instances of *probably*?

In the present article, we try to motivate a picture of what makes some words harder to acquire than others, not only for babies but for other linguistic novices as well. Findings we report suggest that a considerable part of the bottleneck for vocabulary learners is not so much in limitations of the early conceptual repertoire but rather in solving the mapping problem that Locke introduces in (1): determining which phonetic formative expresses which concept. Thereafter, we describe a theory of word learning that in early incarnations was called *syntactic bootstrapping* (Gleitman, 1990; Landau & Gleitman, 1985). In line with most recent commentary in the literature of infant perception and conception, this approach accepts that infants by their first birthday or sooner approach the task of language learning equipped with sophisticated representations of objects and events (e.g., "core knowledge" in the sense of Spelke, 2003; Spelke, Breinlinger, Macomber, & Jacobson, 1992) and quite a smart pragmatics for interpreting the gist of conversation during communicative interactions with caretakers (per Baldwin, 1991; P. Bloom, 2002; and Tomasello & Farrar, 1986).

These capacities enable the learners to entertain a variety of concepts expressed by the words that their caregivers utter. However, although this sophistication with event structure and conversational relevance necessarily frames the word-learning task, we posit that it is insufficient taken by itself. The other major requirement for vocabulary growth is developing linguistic representations of incoming speech that match in sophistication, and dovetail with, their pragmatic and conceptual representations. By so doing, the learners come to add structure-to-world mapping procedures to the word-to-world mapping procedures with which they began. Specifically, the position we defend is that vocabulary learning presents a classic poverty of the stimulus problem that becomes obvious as soon as we turn our attention past the simplest basic-level whole-object terms. For many if not most other words, the ambient world of the language learner is surprisingly impoverished as the sole basis for deriving meanings. Yet children learn these "hard" words, too, although crucially with some measurable delay.

Two broad principles characterize our account. On the one hand, we claim that learners' useable input, both linguistic and nonlinguistic, for word learning is much broader and more varied than is usually acknowledged. But on the other hand, this improved input perspective threatens to create a learning problem that, just as perniciously, substitutes a "richness of the stimulus" problem for the "poverty of the stimulus" problem as previously conceived (cf. Chomsky, 1959; Quine, 1960; see also Gleitman, 1990). The learner who can observe everything can drown in the data. Two kinds of capacity and inclination rescue the learning device. The first is a general learning procedure that can extract, combine, and coordinate multiple probabilistic cues at several levels of linguistic analysis (in the spirit of many machine-learning and constraint-satisfaction proposals; e.g., Bates & Goodman, 1997; Elman, 1993; Goldsmith, 2001; Kelly & Martin, 1994; Manning & Schütze, 1999; McClelland, 1987; Trueswell & Tanenhaus, 1994). However, for such a probabilistic multiple-cue learning process to work at all it requires unlearned principles concerning how language realizes conceptual structures; and similarly unlearned principles for how these mappings can be discovered from their variable and complex encoding in speech within and across languages (e.g., Baker, 2001a; Borer, 1986; Grimshaw, 1990; Jackendoff, 1990; Lidz, Gleitman, & Gleitman, 2003a).

TWO ACCOUNTS OF HARD WORDS

When we compare infants' conceptual sophistication to their lexical sophistication, we find a curious mismatch. Earliest vocabularies all over the world are replete with terms that refer in the adult language to whole objects and object kinds, mainly at some middling or "basic" level of conceptual categorization—for example, words such as *doggie* and *spoon* (Au, Dapretto, & Song, 1994; Bates, Dale, & Thal, 1995; Caselli et al., 1995; Fenson et al., 1994; Gentner & Boroditsky, 2001; Goldin-Meadow, Seligman, & Gelman, 1976; Kako & Gleitman, 2004; Lenneberg, 1967; Markman, 1994). This is consistent with many demonstrations of responsiveness to objects and object types in the prelinguistic stages of infant life (Kellman & Arterberry, 1998; Kellman & Spelke, 1983; Mandler, 2000; Needham & Baillargeon, 2000).

In contrast, for relational terms the facts about concept understanding do not seem to translate as straightforwardly into facts about early vocabulary. Again there are many compelling studies of prelinguistic infants' discrimination of and attention to several kinds of relations, including containment versus support (Hespos & Baillargeon, 2001), force and causation (Leslie, 1995; Leslie & Keeble, 1987), and even accidental versus intentional acts (Carpenter, Akhtar, &

Tomasello, 1998; Woodward, 1998). Yet when the time comes to talk, there is a striking paucity of relational and property terms compared to their incidence in caretaker speech. Infants tend to talk about objects first (Gentner, 1978, 1981). Consequently, because of the universal linguistic tendency for objects to surface as nouns (Baker, 2001b; Pinker, 1984), nouns overpopulate the infant vocabulary as compared to verbs and adjectives, which characteristically express events, properties, and relations. The magnitude of the noun advantage from language to language is influenced by many factors, including frequency of usage in the caregiver input; but even so, it is evident to a greater or lesser degree in all languages that have been studied in this regard (Gentner & Boroditsky, 2001; Snedeker & Li, 2000).[2] In sum, verbs as a class are "hard" words whereas nouns are comparatively "easy." Why is this so?

An important clue is that the facts as just presented are wildly oversimplified. Infants generally acquire the word *kiss* (the verb) before the word *idea* (the noun), and even before *kiss* (the noun). As for the verbs, their developmental timing of appearance is variable, too, with such items as *think* and *know* generally acquired later than *go* and *hit* (L. Bloom, Lightbrown, & Hood, 1975). Something akin to "concreteness" rather than lexical class *per se*, appears to be the underlying predictor of early lexical acquisition (e.g., Gentner, 1978, 1982; Gentner & Boroditsky, 2001; Gleitman & Gleitman, 1997).[3]

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[2]Large differences in the type–token frequencies of nouns and verbs cross-linguistically result from the fact that some languages permit argument dropping (where the content is pragmatically recoverable) much more than others do (see, e.g., Gelman & Tardif, 1998; Tardif, Gelman, & Xu, 1999). But even in such "verb friendly" languages as Korean and Mandarin Chinese, the noun advantage in early learning is still visible, though smaller in magnitude (Gentner & Boroditsky, 2001; Snedeker & Li, 2000).

[3]The idea that the noun advantage is an artifact of the greater concreteness of concepts expressed by the common stock of nouns compared to the common stock of verbs is maintained by almost all investigators of these phenomena, notably, Gentner (1982) whose individuation hypothesis was the first in the modern era to draw attention to the facilitative role of transparent word-to-world mappings (but see Hume, 1739/1978, on simple concepts). The explanatory victory here, as Gentner also notes, is somewhat hollow, because *concreteness* is itself a term in need of considerable sharpening. For instance, a large literature shows that all sorts of words describe concepts whose exemplars are perceptible, so in this sense concrete, but not all of these are equally easy to learn (L. Bloom et al., 1975; Graham, Baker, & Poulin Dubois, 1998; Hall, 1991; Kako & Gleitman, 2004; Markman, 1987). These include, among others, partitives (e.g., *trunk* or *tail* as opposed to *elephant)* and superordinates (*thing* and *animal* as opposed to *dog*; Shipley, Kuhn, & Madden, 1983); proper names (*Daddy* as opposed to *man*; Hall, 1991; Katz, Baker, & MacNamara, 1974); and terms that describe a situation-restricted entity (*passenger* or *lawyer* versus *man*; Hall, 1994). Overall these studies suggest that "basic-level object" (Rosch, Mervis, Gray, Johnson, & Boyes-Braem, 1976) may be closer to the mark than "concrete" (see Hall & Waxman, 1993). For present purposes, and because it is incontrovertible, we accept that something like this aspect of certain concepts is accounting for their transparency to the initial lexical mapping procedures, and we use the approximate term *concreteness* as its nickname. In any case, our main topic in the present work is in the acquisition procedures for Hard Words, issues that are not engaged in the literature on concreteness and the noun advantage.

The Conceptual Change Hypothesis

Plausibly enough, the early advantage of concrete terms over abstract ones has usually been taken to reflect the changing character of the child's conceptual life, whether attained by maturation or learning. Smiley and Huttenlocher (1995) presented this view as follows:

> Even a very few uses may enable the child to learn words if a particular concept is accessible. Conversely, even highly frequent and salient words may not be learned if the child is not yet capable of forming the concepts they encode ... cases in which effects of input frequency and salience are weak suggest that conceptual development exerts strong enabling or limiting effects, respectively, on which words are acquired. (p. 20)

Indeed, the word-learning facts are often adduced as rather straightforward indexes of concept attainment (e.g., Dromi, 1987; Huttenlocher, Smiley, & Charney, 1983). In particular, the late learning of credal, or belief, terms is taken as evidence that the child does not have control of the relevant concepts. In the words of Gopnik and Meltzoff (1997)

> the emergence of belief words like "know" and "think" during the fourth year of life, after "see," is well established. In this case ... changes in the children's spontaneous extensions of these terms parallel changes in their predictions and explanations. The developing theory of mind is apparent both in semantic change and in conceptual change. (p. 121)

The Informational Change Hypothesis

A quite different explanation for the changing character of the vocabulary, the so-called syntactic bootstrapping solution (Fisher, 1996; Gleitman, 1990; Landau & Gleitman, 1985; Trueswell & Gleitman, in press), has to do with information change rather than, or in addition to, conceptual change. Specifically, we propose the following general explanation:

1. Several sources of evidence contribute to solving the mapping problem for the lexicon.
2. These evidential sources vary in their informativeness over the lexicon as a whole.
3. Only one such evidential source is in place when word learning begins; namely, observation of the word's situational contingencies.
4. Other systematic sources of evidence have to be built up by the learner through accumulating linguistic experience.
5. As the learner advances in knowledge of the language, these multiple sources of evidence converge on the meanings of new words. These procedures mitigate and sometimes reverse the distinction between "easy" and "hard" words.

The result of this learning procedure is a knowledge representation in which detailed syntactic and semantic information is linked at the level of the lexicon.

According to this hypothesis, then, not all words are acquired in the same way. As learning begins, the infant has the conceptual and pragmatic wherewithal to interpret the reference world that accompanies caretaker speech, including the gist of caretaker–child conversations (to some unknown degree; but see P. Bloom, 2002, for an optimistic picture, which we accept). These capacities and inclinations to interpret the reference world meaningfully are implicit as well in Locke's dictum (1). Words that can be acquired solely from such confrontations with extralinguistic context are easy in the sense that we have in mind (for a closely related position, see Gentner, 1982).

The output of this observational, word-to-world learning procedure is a substantial stock of basic-level terms, largely nouns. This foundational vocabulary, important in its own right for the novice's early communications with others, also plays a necessary role in the computational machinery for further language learning. Crucially, it provides a first basis for constructing the rudiments of the language-specific clause-level syntax of the exposure language; that is, the structural placement of nominal arguments (a matter discussed later in this article). This improved linguistic representation in turn becomes available as an additional source of evidence for acquiring further words, those that cannot efficiently be acquired by observation operating as a stand-alone procedure. The primitive observation-based procedure that comprises first stage of vocabulary growth is what preserves this model from the vicious circularity implied by the whimsical term *bootstrapping* (you can't pull yourself up by your bootstraps if you're standing in the boots). We now turn to some evidence.[4]

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[4]Three strange misinterpretations of this bootstrapping hypothesis have crept into the mythology of the field, perhaps in part through a misunderstanding of Pinker (1994) or Grimshaw (1994). The first is that the idea is for the child to give up use of the extralinguistic context of input speech as a cue to word meaning once he or she achieves control of the semantics of syntactic structures, substituting internal linguistic analyses. Nothing could be further from the truth or from any proposal that our group of investigators has ever made: The proposal has always been that word-to-world pairing comes to be supplemented by structure-to-world pairing (Landau & Gleitman, 1985). The "world"—that is, the extralinguistic concomitants of word use—never disappears from the learning equation. The second misunderstanding is that linguistic structure can directly reveal the "full meaning" of verbs. To believe any such thing would make a mystery of the fact that we learn many verbs whose syntactic properties are the same (e.g., those for *freeze/burn* and those for *bounce/roll;* see Fillmore, 1970). Of course, syntactic structure can reveal only the argument-taking properties of verbs, which constrains—but does not exhaust—their semantics. The third misconception is that according to our hypothesis you could never learn the meaning of any verb without syntactic support. That would make a mystery of the fact that Spot and Rover can understand "roll over" and "give me your paw" given enough dog bisquits. We are talking about the basis for *efficient* learning ("fast mapping" per Carey, 1978).

THE HUMAN SIMULATION PARADIGM (HSP) AND THE LEARNING OF EASY WORDS

In several recent studies we investigated the mapping problem in lexical learning under varied informational conditions (Gillette, Gleitman, Gleitman, & Lederer, 1999; Snedeker & Gleitman, 2004; Kako & Gleitman, 2004). The first purpose of these studies was to investigate the potency, in principle, of various kinds of situational and linguistic cues for identifying the concept that individual words (common nouns and verbs) encode. Of course, findings of this kind do not necessarily imply that learners can or do recruit these cues for use in word learning. This limitation has made it seem to some critics paradoxical, if not perverse, that we chose adults as the participants—the word learners—in these simulations. After all, what we want to understand is why the learning sequence for the vocabulary in young children describes the trajectory that it does. So why study adults? The answer has to do with our second aim. An adult population provides a first method for disentangling the conceptual change and the information change hypotheses. If the character and trajectory of learning differ greatly between children and adults as a function of the vast conceptual gap between these populations, then we should not expect to be able to model infant learners of vocabulary with adults. But what if we can make perfectly sophisticated (well, reasonably sophisticated) undergraduates learn as babies learn simply by withholding certain kinds of information? And what if that withheld information was just the kind of language-particular information that the baby could not have? Such a result would bolster an information-change account. Thus the Human Simulation Paradigm (HSP) is designed to model the target population (infants) by investigating effects of input on the learning function in adults, much in the vein of computer simulations of this process (see Webster & Marcus, 1989, for the first computer simulation of verb learning in this line, based on the outline scheme in Landau & Gleitman, 1985).

HSP derives its choice of materials from a realistic source: a database of approximately 30 hr of conversations collected under naturalistic circumstances between English-speaking mothers and their infants, aged about 18 to 24 months. The test items were the 24 most frequent nouns and the 24 most frequent verbs that occurred in these conversations. To test how easy or hard it might be to identify these words from extralinguistic context alone, adult observers were shown video clips (each about a minute in length) chosen by a random procedure, of the mothers' child-directed speech.[5] Crucially, the tapes were silenced, but an audible beep occurred whenever the mother uttered the "mystery

[5]This choice of stimulus materials has another advantage in realism over most laboratory probes for lexical acquisition: The learner is presented with a complex videotaped reference world—that is, an undoctored, ongoing interaction between mother and child in a setting filled with all the objects and fleeting actions of everyday life and in a long-enough segment for the gist of the conversation to be extracted. This is in comparison with the usual laboratory tasks for child learners in which they are offered

word." Participants saw six such clips for each word, presented in a row, and were told that each series of six beeps marked utterances of the same word by the mother. Thus they were being asked to identify words (perform the mapping task) by word-to-world pairing, conjecturing the meaning of each of the mystery words by observation of the real-world contingencies for its use. The six exemplars provided the participants with an opportunity for some cross-situational observation to guide the interpretation of each word in situational context. In the initial studies they were told whether the words were nouns or verbs. Nouns were overwhelmingly easier for the participants to identify (45% correct) than verbs (15% correct) in this situation, in which number of exposures was the same. In a replication by Snedeker and Gleitman (2004) the massive advantage of the nouns over the verbs remained, even when the beeps were not identified by lexical class. Thus these results reproduced the noun-dominance property observed for babies as they first begin to speak.

Success rates in this task could be predicted by other participants' judgments of the concreteness of each word in the set of 48 items. On average, the test nouns in the mothers' speech were judged more concrete (or more imageable) than the verbs, and these concreteness scores were much better predictors of success rate on the identification task than the noun–verb distinction. Within lexical class, the same results hold. For example, Kako and Gleitman (2004) found that words for basic-level categories of whole objects (*elephant*) are strikingly easier to identify in this paradigm based on observation alone than are abstract nouns (*thing*). Similarly, the most concrete verbs (*throw*) were correctly identified relatively frequently, whereas the most abstract verbs (*think, know*) were never guessed correctly by any participant . What is important here is that the concreteness factor that determined adult behavior in the HSP laboratory also characterizes the infant's first vocabulary, as earlier described by Gentner (1982): an overpopulation of concrete nouns, an underrepresentation of verbs (compared to their frequency in input speech), and a total absence of credal terms.

Taken at their strongest, these results suggest that the chief limiting factor on early vocabulary growth resides in the tools and information available for solving the mapping problem, rather than in limitations in conceptual sophistication. This is so, even though we can think of our adults in this task as doing something like second-language acquisition. Already knowing the words *ball* and *think* in English and the concepts that these encode, they learned that "beep" means 'ball' more easily than they learned that "beep" means 'think' just because they were discovering the

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a few structured alternatives in a stripped-down environment—for example, the learner is confronted with a limited set of test objects that differ only in, say, size, shape, or color; or in thingness and stuffness. In the real environment of learners, to the extent simulated here, the world is so richly and variously specified that the mapping problem is exposed in something like its true buzzing blooming confusion (cf. Chomsky, 1959; for discussion of this factor in HSP, see Kako & Gleitman, 2004).

mappings by using the evidence of their senses. The suggestion is that, in a related sense, infant vocabulary acquisition is second-language learning as well.[6]

As we next discuss, the initial stock of lexical items acquired via word-to-world pairing eventuates not only in a primary vocabulary. These items play a crucial further role in language learning. They form the scaffold on which further linguistic achievements—both lexical and phrase structural—are built.

HSP AND THE LEARNING OF HARD WORDS

How does the child move beyond an initially concrete, largely nominal vocabulary? The indirect relationship between verb meaning and observed events renders verb learning in particular somewhat mysterious. For one thing, verb occurrence is apparently not time locked with event occurrence to anything like the extent that noun occurrence is linked to object presence (Akhtar & Tomasello, 1997; Gleitman, 1990). Second, there is much more surface variability in how verbs get realized and encoded grammatically than nouns within and across languages (Baker, 2001a; Gentner, 1982; Gentner & Boroditsky, 2001; Goldberg, 2004; Lidz et al., 2004). Third, as we discuss later, some verbs represent concepts so divorced from everyday perception that the observed scene is almost wholly opaque for gleaning their intent. For these hard words the learner needs supplementary evidence—linguistic evidence bootstrapped from (grounded by) the early-acquired vocabulary of concrete words. To illustrate, let us return to the HSP simulation procedures.

To study the effects of changing the input database for learning, we next asked adults to identify nouns and verbs spoken to young children based on various combinations of linguistic and extralinguistic information (Gillette et al., 1999; Kako & Gleitman, 2004; Snedeker & Gleitman, 2004). The test items were the same ones for which we had previously shown the silenced video clips: the six randomly selected instances for each of the 24 most frequent nouns and the 24 most frequent verbs in our sample of maternal child-directed speech. Groups of adult participants were again asked to guess these words, but each group was provided with different, potentially informative, sources of evidence.

Table 1 illustrates these sources of evidence for the six instances of the mothers' uttering the verb *call*. The first source of evidence was again the video-clip scenes. The second, a linguistic source, was the presence of the other content words in the mother's utterances (in this case, the Nouns); these were presented in alphabetical order (within sentence) to avoid cueing the syntax. The third source of evidence,

[6]"But if the knowledge which we acquired before birth was lost by us at birth, and afterwards by the use of the senses we recovered that which we previously knew, will not that which we call learning be a process of recovering our knowledge, and may not this be rightly termed recollection?" (Plato, *Phaedo* [ca. 412 BCE])

TABLE 1
The Information Sources Provided to Participants in the Human Simulation Paradigm for the Item "call"

Task	*Information Source Provided to Participants*
What does GORP mean?	Scenes: Six video clips of mother–child interactions (no audio, single beep played at time of mystery-word utterance).
What does GORP mean?	Nouns that occurred in the six maternal utterances (alphabetized): *Gramma, you* *Daddy, Daddy* *Daddy, you* *I, Markie* *Markie, phone, you* *Mark*
What does GORP mean?	Frames in which the six maternal utterances occurred: *Why don't ver GORP telfa?* *GORP wastorn, GORP wastorn.* *Ver gonna GORP wastorn?* *Mek gonna GORP litch.* *Can ver GORP litch on the fulgar?* *GORP litch.*

Note. This table was adapted from Gillette, Gleitman, Gleitman, and Lederer (1999).

again linguistic, was the set of syntactic Frames in which the test items had occurred in the six test maternal utterances. To construct such frames, we simply replaced the content words and the mystery word itself (in caps) by nonsense forms, much in the spirit of Lewis Carroll's *Jabberwocky* (see also Epstein, 1961). Three groups of participants were each presented with one of these three evidential sources, and the other participant groups received various combinations of these cues, sometimes including and sometimes excluding the video clips.

How well did participants do when guessing the mystery word under these different information conditions? Figure 1 (adapted from Snedeker & Gleitman, 2004) shows the accuracy scores for each information condition and their combinations. As seen in the figure, participants who got just the Nouns did about as well as those who got just the silenced videotaped Scenes (about 15%). Those who were provided with both sources of information were significantly more accurate; indeed, the effects of the two sources of evidence are roughly additive, yielding an accuracy score of about 30% correct, an instance of the cooperative use of cues (a subject to which we will return at length). Interestingly, participants who got explicit syntactic information about the verbs' original contexts of use (the Frames condition) did better than those who got only Nouns or only Scenes and even did better than those who got both of these latter cues. Adding the Scenes to the Frames improved performance to well over 50% accuracy, as did giving participants the Nouns and the Frames. And, of course, performance

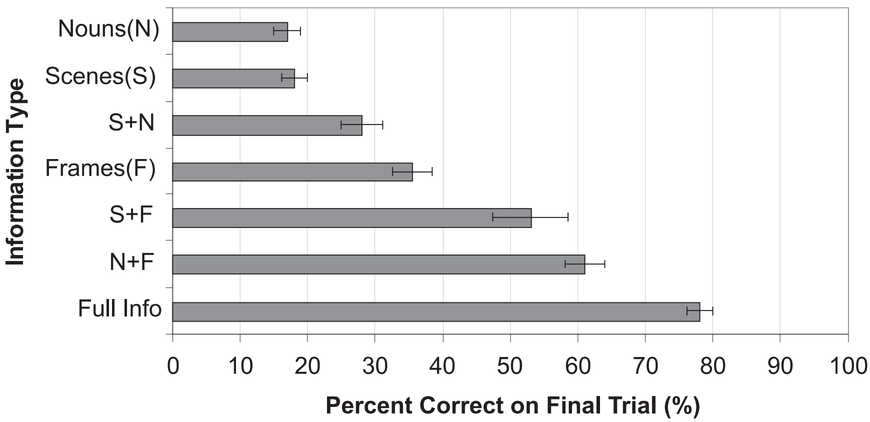

FIGURE 1 Percentage of correct identification of the "mystery word" in the Human Simulation Paradigm as a function of the type of information supplied to the participants. Adapted from Snedeker and Gleitman (2004).

was best (nearly 80% correct) when the full range of information was provided (Nouns, Scenes, and Frames). When it is realized that each participant group was exposed to only the six randomly chosen instances for each verb as the basis for learning, the accuracy rates with these improved databases is truly impressive. Learning how verbs map onto possible events in a scene seems to be a snap in the presence of noun knowledge and knowledge of the clause-level syntax.

Most relevant for our present purposes, these findings dovetail nicely with the findings from the earliest stages of vocabulary growth in children. For the first hundred words or so, learning is slow and heavily favors concrete nouns that express basic-level whole-object concepts. At this stage, most infants give little evidence of competence with the syntax of the exposure language; they are mainly one-word-at-a-time speakers. At the next stage, the rate of vocabulary learning roughly triples, with all word classes represented. This stage is contemporaneous with the time at which rudiments of syntactic knowledge are evident in speech (for prior statements that these lexical and syntactic achievements are causally linked, see Bates & Goodman, 1997; L. Bloom, 1970; Gleitman & Wanner, 1982; and Lenneberg, 1967).

Perhaps the most striking revelation from the HSP data concerns the trade-off in the weighting (informativeness) of various cues in predicting accuracy scores for different kinds of words.[7] As mentioned earlier, Gillette et al. (1999) found through a set of correlational analyses of HSP performance that only highly con-

[7]In evaluating these findings, please keep in mind that we are always testing accuracy scores for the 48 most frequent nouns and verbs from a sample of spontaneous speech of mothers to their babies. And mental-content words such as *want* and *think* do show up on these highest-frequency lists.

crete terms benefited in their learning from the presence of Scenes, whereas the more abstract words benefited primarily from the language-internal information. For example, Scenes were the overwhelmingly potent cues to identifying *go* and were completely uninformative for *know* (zero accuracy score); symmetrically, participants were almost perfect in identifying *know* from its syntactic environments but were helpless to do the same for *go*. Figure 2 shows this cue-trading effect in a different and more transparent way. Snedeker and Gleitman (2004), using new materials and new participants, compared accuracy scores for a subset of the test items: action verbs (relatively concrete) versus mental-content verbs (abstract verbs of perception, communication, and thinking). As the items become more abstract, language-internal cues become most informative for their identification. This outcome really should come as no great surprise. To the extent that thinking takes place invisibly, inside nontransparent heads, the intent to express it could not be literally revealed by observing the objects and events that are in view (excepting, perhaps, the sight of certain Rodin statues). This generalization is the contrapositive to Yogi Berra's dictum:

(2) If it's not something you can observe, then you're not going to learn it by watching.

Some sophisticated linguistic knowledge of the exposure language is required to support the learning of these hard words.

Before concluding this section we want to point out that several machine-learning investigators have in recent years performed computer simulations that are relevant to and supportive of the claims made here and that these findings have in most cases behavioral evidence to back them, showing that humans can (to say the least!) do just as well as the Macs, PCs, and Sun Workstations in this regard. One finding from that literature is that subcategorization frame sets (of the kinds exemplified in Table 1) can be extracted from large corpora by automatic data-manipulation procedures and assigned to specific verbs (Brent, 1994; Manning, 1993; Mintz, 2003). The incredible facility of young babies in performing distributional analyses of the kinds that these simulations use is of course well attested—most notably for syllables (Saffran, Aslin, & Newport, 1996) but for other analytic levels as well (Goldsmith, 2001; Jusczyk et al., 1992; Morgan, Meier, & Newport, 1987). Second, corpus analyses of speech to children (Lederer, Gleitman, & Gleitman, 1995) including cross-linguistic studies (Geyer, 1994; Li, 1994), correlational studies with adults (Fisher, Gleitman, & Gleitman, 1991), and several computer simulations with large corpora (Dorr & Jones, 1995; Dang, Kipper, Palmer, & Rosenzweig, 1996; Li, 2003; Merlo & Stevenson, 2001) provide convergent evidence that syntactic subcategorization frame overlap is a powerful predictor of semantic relatedness.

Thus when we measure how the adult participants score in identifying words such as *want, look,* and *think*, we are testing items that show up again and again in the speech input to infants, rather than some exotic or unmotivated sets of items.

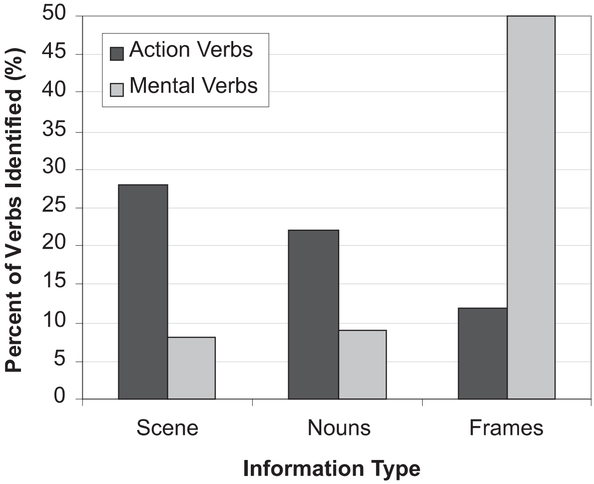

FIGURE 2 Informativity across verb types. Percentage of correct identification of the "mystery word" in the Human Simulation Paradigm as a function of verb class and the type of information supplied to the participants. Mental verbs are better identified by syntactic frame information, whereas action verbs are better identified by Scene information and by Noun information. Adapted from Snedeker and Gleitman (2004).

HOW INCREASING LANGUAGE KNOWLEDGE SUPPORTS VOCABULARY GROWTH: A PROBABILISTIC MULTIPLE-CUE PERSPECTIVE

Demonstrably, then, language-internal cues help in the solution to the mapping problem. We now begin to describe why this should be so. How can mere structure cue the semantics of words? We attempt to answer this question in the remaining sections of this article by offering an informal model of word and phrasal learning in this regard. We consider first how the evidential sources that we identified earlier might support abstract word learning. We then offer a solution that is later explored and refined by experimental findings (the section entitled "How Does the Child Acquire the Syntactic–Semantic Linkages?").

Distributional Cues

Knowing some of the words in a sentence narrows the space of plausibilities for what other, unknown, words in that sentence might mean (Harris, 1964; Resnick, 1996; see also, Pinker, 1989). Figure 1 shows this effect for participants in HSP, whose accuracy given distributional information (Nouns) equals the accuracy of participants who were shown extralinguistic context (Scenes), about 15% correct. Thus there is some degree of recoverable inference from a word to its positional neighbors. It is easy to illustrate why this is so: *Drink* and *eat* are not only transitive verbs; they systematically select animate subjects and direct-object nouns that express potables and edibles. Young children are sensitive to this sort of information. For example, 2-year-olds move their eyes to a picture of a glass of juice, rather than to a picture of a nonpotable object, upon hearing the familiar verb *drink* and before hearing the actual noun object (Chang & Fernald, 2003). And they successfully induce the referent of a new word introduced in an informative context as the object of a familiar verb, for example, "She's feeding the ferret!" (Goodman, McDonough, & Brown, 1998). Adults also make very rapid online decisions about what the object of the verb must be, given the verb's meaning. For instance, as soon as they hear "The boy ate … ," they direct their gaze to objects in the scene that can be eaten (Altmann & Kamide, 1999; Kako & Trueswell, 2000). In general, they rapidly constrain the domain of reference of upcoming constituents to multiple objects with appropriate semantic affordances that compete for referential consideration.

Clearly, this cue will vary in its informativeness depending on the type of word. Thus, because one can find or see practically anything, distributional cues to words expressing these concepts will be far weaker than they are for such verbs as *fold* or *break*, which suggest soft and brittle things, respectively (Fillmore, 1970). Moreover, like all cues that we will be describing, the information will be probabilistic rather than determinative, as it must be if language is to express rare and even bizarre ideas. For instance, there are two instances in our corpora of maternal speech of the sentence *Don't eat the book*. Finally, whether distributionally related items are likely to be contiguous will also vary to some degree as a function of language type (see Mintz, 2003).

Syntactic Information

The results of the HSP suggest that syntactic information—in this case, subcategorization frame information—is a powerful inferential cue to verb meaning. Again, it is easy to see the basis for why. Verbs vary in their syntactic privileges (that is, the number, type, and positioning of their associated phrases). These variations are systematically related to the verbs' meanings (Chomsky, 1981; Dang et al., 1996; Fisher, 1996; Fisher et al., 1991; Gleitman, 1990; Goldberg, 1995; Grimshaw, 1990; Jackendoff, 1990; Joshi & Srinivas, 1994; Levin & Rappaport Hovav, 1995; Pinker, 1989; Tanenhaus & Carlson, 1988, *inter alia*). A verb that describes the motion of an object will usually occur with a noun phrase that specifies that object; a verb that describes action on an object will typically accept two noun phrases (i.e., be transitive), one for the actor and one for the object; a verb that describes transfer of an object from one place to another will take three arguments, one each for the moving thing and for its source (start point) and goal (end point). Similarly sensible patterns appear for argument type: A verb such as *see* can take a noun phrase as its complement because we can see objects, but it can also take a sentence as its complement because we can perceive states of affairs (for discussion in the context of blind children's competence with such perceptual terms in the absence of experience, see Landau & Gleitman, 1985).

These syntactic–semantic correspondence patterns show strong regularities across languages (Baker, 2001a, 2001b; Croft, 1990; Dowty, 1991). These cross-linguistic regularities have long been taken to be primary data for linguistic theories to explain, leading to significant linguistic generalizations such as the theta criterion and the projection principle (Chomsky, 1981), which jointly state that the noun phrases in sentences must be licensed by the right kind of predicate (one that can assign them a thematic, or "theta," role) and that clause structure must be projected from lexical entries. Similarly, unlearned constraints linking thematic roles such as *agent* and *theme* to the grammatical functions *subject* and *object* have been proposed to explain striking cross-linguistic regularities in the assignments of semantic roles to sentence positions. Causal agents, for example, overwhelmingly appear as grammatical subjects across languages (Baker, 2001a; Keenan, 1976).

Based on these systematic links between syntax and meaning, the adults in Gillette et al.'s studies were able to consult each verb's sentence structure—implicitly, of course—to glean information about the semantic structure of the verb in that sentence. The observed sentence structure, by specifying how many and what types of arguments are being selected by the verb, provides a kind of "linguistic zoom lens" to help the learner detect what is currently being expressed about an ongoing event or a state or relation (Fisher, Hall, Rakowitz, & Gleitman, 1994). Recent evidence documents that young children, like adults, use these verb–syntactic correspondences in real-time to parse sentences and resolve ambiguity (e.g., Trueswell & Gleitman, in press; Trueswell, Sekerina, Hill, & Logrip, 1999).[8]

All the same, it has sometimes been questioned how significantly distributional and syntactic information can really aid in verb learning (e.g., Pinker, 1994; Woodward & Markman, 2003). The reasons for skepticism have to be answered if the model we propose is translatable as a true picture of the processes underlying vocabulary growth and early phrase structural learning in infants. We briefly mention some of these problems here to clarify how the model approaches their solution. Thereafter we turn to behavioral findings that support the model and further specify the account.

A paucity of structural distinctions and the zoom lens hypothesis. There are only a few scores of basic phrase structure types in a language. Yet there are thousands of verbs and verb meanings. Then how much of a constraint can the struc-

[8]The structured lexical entries necessarily built in the course of learning are used as well in building an efficient, dynamic language-processing system—a system that in the adult state automatically retrieves detailed syntactic tendencies of individual verbs "on the fly" as they are encountered. This allows an accurate estimation of the sentence structure to be recovered rapidly enough by listeners so as to assign meaning and establish reference almost on a word-by-word basis (e.g., Kim, Srinivas, & Trueswell, 2002; MacDonald, Pearlmutter, & Seidenberg, 1994; Trueswell & Tanenhaus, 1994; Trueswell, 2001).

ture provide? For any particular occurrence of a novel verb in a frame, only some exceedingly coarse narrowing of the semantic range of that verb is possible. But what this syntactic information lacks in specificity, it makes up for in establishing saliency. When paired with a scene, the structural properties of an utterance focus the listener on only certain aspects of the many interpretations that are always available to describe a scene in view. Consider in this regard a study from Naigles (1990). She showed infants (average age 25 months) a videotaped scene in which there were two salient happenings: A duck and a rabbit were each wheeling one of their arms in a wide circle as the duck was pushing the rabbit down into a squatting position. Some infants heard a voice saying, "Look! The duck and the rabbit are *gorping*." The others heard, "Look! The duck is *gorping* the rabbit!" The two introducing sentences differ in that one exemplifies a one-argument intransitive construction and the other exemplifies a two-argument transitive construction. According to the principles relating structure and meaning, only the two-argument construction can support a causal interpretation. But can babies of this age—most of whom have never uttered a verb or even a two-word construction of any kind in their short life—make this same inference? The answer is yes. When the two scenes were later disambiguated on two separate videoscreens (one showing the pushing without arm-wheeling, the other showing arm-wheeling without pushing), babies' dominant gaze direction was shown to be a function of the syntactic introducing circumstances.

Notice that the syntactic information that was provided could not, and therefore did not, directly cue the meaning, say, "arm-wheeling." There is no "arm-wheeling structure" in English or any language. At best, the syntactic information could only, and therefore did only, signal the distinction between a self-caused act (intransitive) and an other-caused act (transitive). If these babies learned that the statement "The rabbit and the duck are gorping" meant 'They are wheeling their arms' (something that the manipulation cannot reveal), then that conjecture is based on two cues converging on the same solution: the information in the scene and the collateral, argument-specifying information in the syntax.

In sum, a single syntactic cue can play only a focusing role: It causes the listener to "zoom in" on one salient aspect of an ambiguous scene. Because we believe, along with Chomsky and Quine and Goodman, that every scene is multiply ambiguous and even "saliently" so, this zoom lens function is crucial in solving the mapping problem for verbs.

Refined semantic information from the matrix of subcategorization frames. In the Naigles study just described, the learning situation was modeled for circumstances in which the learner is provided with only a single scene by syntax pair. But notice that in the HSP nonsense-frame manipulation (Table 1), participants were provided with half a dozen exemplars of the structures licensed for the mystery word, as spoken by the mother. The semantically powerful role that these multiple frames play—both in learning and in sentence processing throughout life— derives from the fact that they successively narrow the semantic range of single verbs. Each frame that a verb naturally accepts provides an indication of one of its allowed argument structures; and the set of frames associated with single verbs provides convergent evidence as to their full expressive range (Fisher & Gleitman, 2002; Gleitman & Fisher, in press; Landau & Gleitman, 1985; Levin, 1993).

Very few verbs share all their syntactic privileges; for many verbs, their licensed frame set may be close to unique. Much more interestingly, overlap in verbs' syntactic range is a powerful measure of their semantic relatedness, as has been shown in correlational studies with adults (Fisher et al., 1991) and in analyses of the input speech to young children (Lederer et al., 1995). Moreover, as we move from language to language, we see that the same frame sets are associated with the same syntactic generalizations over a substantial range (e.g., Baker, 2001b; Geyer, 1994). To give an intuitive feel for the power of syntactic overlap for semantic interpretations, we can do no better than to quote Zwicky (1971), who makes this point forcefully:

> 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., 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 their greem frighten the baby, to greem to me that my examples are absurd, and to give a greem when you see the explanation (p. 232).

Notice then, that while there are only scores of individual subcategorization frames, there are hundreds of thousands of distinct combinations in which these can occur, vastly more than the number of verbs in any language. In other words, the verb by frame matrix is sparsely populated, with the effect that the convergence of frames can and often does yield a rather precise picture of the expressive range of any verb. In Figure 3 we show some of this convergency for a set of verbs in frames (theoretically including *greem*).

A potential practical limitation. Though we cannot discuss this important issue at length in the present article, we do want to point out that the mapping between argument structure and surface sentences is complex and indirect, rendering the rosy picture just painted much more difficult than it seems at first glance (and is the meat and potatoes of generative grammar). Thus even though *give* is (or is claimed to be) a three-argument predicate, it often shows up in real utterances with only two noun phrases, as in "Give me your hand." This argument number–noun-phrase number mismatch often looks materially worse for languages that allow more extensive argument dropping at the surface than English does (e.g., Korean or Mandarin Chinese). Verbs in such languages often appear with fewer than their (supposedly) required arguments represented as overt noun phrases (Rispoli, 1989).

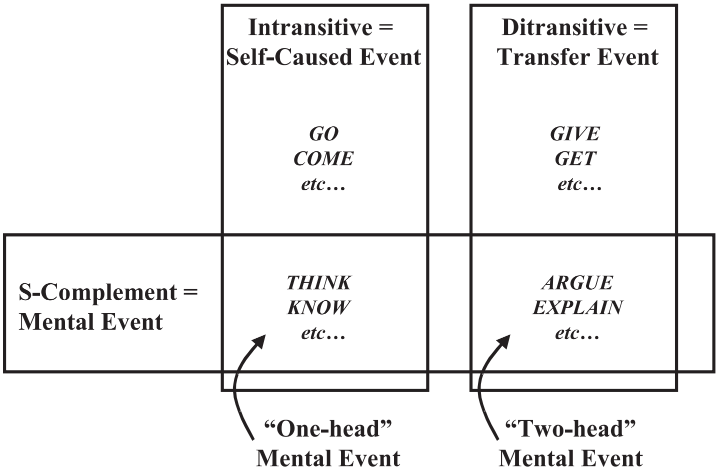

FIGURE 3 A partial subcategorization matrix illustrated for eight Verbs: Verbs that can describe self-caused acts such as *come, go, think,* and *know* license one-argument intransitive constructions when they do so; verbs that can describe transfer events, such as *give, get, argue, explain,* appear in three-argument ditransitive constructions when they do so; verbs such as *think*, *know*, *argue* and *explain,* which can describe the mental relation between an entity and an event, appear in tensed sentence–complement constructions (S-complement) when they do so. Taken together, then, *give* describes the transfer of physical objects (three arguments but not sentence complements) whereas *explain* describes the transfer of mental objects, such as ideas—that is, communication—and so licenses both three-argument and S-complement structures (*John explains the facts to Mary; John explains [to Mary] that dinosaurs are extinct*). In contrast, the intransitive possibilities of *come, go, think,* and *know* reflect their independence of outside agencies; that is, thinking is "one-head cognition." Notice also that unlicensed frames, if uttered, add their semantics to known verbs. For example, "John thinks the ball to Mary" would be interpretable as an instance of psychokinesis.

However, this variability is systematic; that is, the generalizations implicit in the data set have to do with such properties as the maximum number of noun phrases that a verb "ever" allows, and in large frequency differences of verb occurrence within different frames. Even in English we may say, "John gives a book to Mary" or "John gives at the office" or "Something's gotta give." But the difference between *give* and, say, *snore* or *sleep* is that these latter verbs, unlike *give*, are vanishingly rare in ditransitive (three-argument) structures and predictably metaphorical when they so occur (*The reader may be sleeping his way through this article*). In languages with a significant proportion of argument-dropped utterances, this relationship remains systematic: As a statistical matter, the verb meaning 'give' continues to occur with a larger number of overt noun phrases than does the verb meaning 'hit,' and *mutatis mutandis*, for 'snore.' (For a discussion of the complexity of noun phrase to argument relations in languages and their relation to the syntactic bootstrapping hypothesis, see Lidz, Gleitman, & Gleitman, 2003a; Lidz & Gleitman, 2004.)

HOW DOES THE CHILD ACQUIRE THE SYNTACTIC–SEMANTIC LINKAGES?

We have just reviewed the ideas behind the syntactic bootstrapping hypothesis for lexical learning. However, we have so far left aside fundamental questions about how the infant could ever make contact with, and come to exploit, a system of language-to-thought mappings of the kinds just posited. We turn now to two such questions.

The Unlearned Character of Predicate–Argument Structure

To an interesting extent, prelinguistic infants naturally factor their representations of events into conceptual predicates and arguments. A particularly striking piece of evidence comes from recent habituation and eye-movement studies (Gordon, 2003) in which infants were shown videos depicting *giving* or *hugging*. In the former, two people approach each other; one hands a large stuffed bear to the other; and then they part. In the latter, two people approach each other, embrace, and then part. The clever part of this manipulation is that in both scenes one of the two participants is holding a large floppy stuffed toy. The only difference between the two depicted events in this regard is that only in the *give* scene is this toy transferred from one participant's grasp to the other's before the two separate. Once babies were habituated to such scenes, they viewed new scenes that were identical to the originals except that the toy was now absent. The habituation results and, most interesting, the infants' eye movements demonstrated that the infants visually searched for the missing toy in these new *give* (or *give*like) scenes but not in the new *hug* scenes. For the new *give* scenes, they gazed at the area of the two people's hands, as if searching for the missing toy. In contrast, they did not seem to notice much difference (they did not dishabituate) when a yellow flopping bear was suddenly no longer in view in new scenes of hugging. They did not even look toward the hand of the person who previously held it, nor did they give other measurable signs that they were thinking, "Whatever happened to that yellow bear?" Apparently, the babies' implicit supposition was that, even though stuffed bears are of great interest in everyday life, hugging events are not "relevantly" changed as a function of whether one of the huggers is holding one of them during the performance of this act. But an act of giving is demolished if the potential present does not change hands.

How Arguments Map Onto Syntactic Representations

We have just sketched evidence that infants factor their experience into the things and their doings—that, for babies just as for us adults, the act of, say, a kangaroo jumping comes apart "naturally" into the kangaroo and his jumping. The most central question for our proposal remains to be discussed: What suppositions (if any) does the learner make regarding how these natural parts are to be mapped onto linguistic representations? In this regard we now discuss three principled ways that languages—and the babies who come to learn them—realize predicate–argument structure in the form of the linguistic clause, thus rendering the learning of hard words easy (or at least easi*er*). These mappings relate to three essential variables in argument structure representation in language and thought: argument number, argument position, and argument type.[9] As we sketch these mappings and the evidence for how their discovery supports acquisition of the vocabulary, we will be emphasizing the role of multiple probabilistic cues. This is critical because each of these cue types is unreliable when taken by itself. Efficient learning of the abstract vocabulary is made possible by the fact that these cues *trade* (one does service when the next is unavailable or uninformative) and *conspire* (several cues converge on the same conjecture).

Argument number and noun phrase number. We have already looked at some evidence (Naigles, 1990) that young language learners expect a simple mapping between predicate–argument structure and the design of the clause, namely,

(a) Each thematic (argument) role receives a "slot" in the clause.

This is an informal statement of the linguistic principle known as the theta criterion (Chomsky, 1981). A child acquiring a language might expect this principle to be realized in the number of noun phrases that appear in construction with the verb.

(b) Every argument is realized as a noun phrase in sentences as uttered.[10]

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[9]Of course, many other linguistic properties, including morphology and modal structure, can also provide cues for verb discovery. But we do not have direct evidence in these cases, so we discuss them no further. Keep in mind also that the systematic islands of sameness in syntactic–semantic linkages within and across languages that we now discuss (following Baker, 2001a, *inter alia*) coexist within a sea of differences, also real. Gentner's (1982) natural partitions hypothesis emphasized these differences in cross-linguistic "conflation" patterns in particular as one causal factor in the infant's late learning of verbs as opposed to nouns. We agree. There is a variability in these regards that learners must reckon with, and which renders the acquisition of a language a formidable computational problem. But the considerable differences at the surface should not blind us to the reality and theoretical centrality of the cross-linguistic communalities at the interface of syntax and semantics. What we are discussing are these universal mapping principles that undergird the learning of hard words.

[10]As mentioned earlier, such a principle can be realized only probabilistically in the surface forms of utterances because, among many other reasons, certain constructions (such as the English imperative) systematically render one argument covertly. Moreover, the child learner will have to engage in some fancy footwork to discover these relations from real input as he or she is often in the position of solving for more than one unknown at one time; that is, the ditransitive frame may be truly informative for the semantics of transfer, but the child making this inference must somehow assign this structure upon hearing, say, "John put a ball on the table" and not "John saw a ball on the table." For some discussion of the computational problems that must be faced in this regard, see Lidz and Gleitman (2004).

Perhaps the most revealing evidence in favor of (b) being quite literally an expectation of learners as to how languages are designed comes from observation of isolated deaf children and the languages they devise without a formal linguistic model. Most congenitally deaf children are born to hearing parents who do not sign; therefore, such children may not come into contact with gestured languages for years. Their deafness also makes it impossible for them to acquire the language spoken in the home. Children in these circumstances spontaneously invent gesture systems called *home sign*. Remarkably, although these children are isolated from exposure to any conventional language, their home sign systems partition their experience into the same basic elements that characterize known human languages. These communicative systems have nouns and verbs, distinguishable from each other by, among other indicants, their distinctive iconic properties. For instance, an outstretched hand, palm up, denotes 'give.' In an early study of 6 children in these circumstances, Feldman, Goldin-Meadow, and Gleitman (1978; for a definitive statement and evidence, Goldin-Meadow, 2003b) were able to show that the number of noun phrases in these children's gestured sentences was a function of the verb's argument structure, with the number of signed arguments systematically related to the argument structure of each verb, in accordance with (a) and (b). Intensive study of the syntactic character of these self-devised systems shows that the same principles arise again and again in different cultural environments and in contexts where the surrounding linguistic community is speaking languages as different as Chinese and English (see Goldin-Meadow, 2003a, for a full theoretical and empirical treatment of self-invented sign systems and their crucial status for understanding language learning). Adding materially to this picture are studies of the elaboration and formalization of such systems when home signers form a stable community that maintains its social integrity across time, as in the recent emergence of Nicaraguan Sign Language (Senghas, Coppola, Newport, & Supalla, 1997). Thus, the same fundamental relationships between verb meaning and clause structures surface in the speech of children who are acquiring a conventional language and in the gestures of linguistically isolated children who must invent one for themselves.

Another way to study children's respect for the alignment between argument number and event participants is by testing how they semantically extend known verbs when these are heard uttered in novel syntactic contexts. Naigles, Gleitman, and Gleitman (1992) and Naigles, Fowler, and Helm (1992) asked 2- to 5-year-olds to act out sentences using a toy Noah's ark and its associated characters. The informative trials were those in which a familiar verb was presented in a novel syntactic environment, as in "Noah brings to the ark" or "Noah goes the elephant to the ark." The children adjusted their interpretation of the verb to fit its new syntactic frame, for example, acting out *go* as 'cause to go' (or 'bring') when it occurred ditransitively and *bring* as 'go' when it occurred intransitively. The important generalization here is that semantic extensions of these verbs in novel linguistic contexts are precisely what is expected if the child implicitly honors (a) and (b).

A further informative manipulation is from Fisher (1996). She showed 2.5-, 3-, and 5-year-olds unfamiliar motion events, describing them with nonsense verbs. The verbs were presented either transitively or intransitively. The sentences contained only pronouns that did not distinguish between the all-female characters depicted—for example, *She's pilking her over there* or *She's pilking over there.* Thus the sentences differed only in their number of noun phrases. Children's interpretations of the novel verbs were tested by asking them to point out in a still picture of the previously demonstrated event which character's role the verb described—*Who's pilking over there?* or *Who's pilking her over there?* Adults and children at all three ages were more likely to select the causal agent in the event as the subject of a transitive verb than as the subject of an intransitive verb. Just as for the adult judges in the Gillette et al. studies, these findings provide evidence that the number of noun phrases in the sentence—here without information from noun labels regarding the grammatical subject—influences even 2-year-olds' interpretations of verbs. Compare these results with the innovations of the home signers who invented their own manual communication systems. In both cases, children seem to be biased to map participants in a conceptual representation of an event one to one onto noun arguments in sentences.

One further crucial question should be raised concerning the status of these principles for learners. Are they acquired by induction from the statistical preponderances manifest in a particular language, as proposed by Tomasello (2000) and Goldberg (2004); by the product of unlearned expectations, as the home signer data seem to suggest; or both? To find out, it is useful to look at a language for which the alignment of noun phrases with arguments is partially masked, indeed heavily supplanted by alternative coding machinery. Lidz and colleagues (Lidz & Gleitman, 2004; Lidz et al., 2003a) performed such a test by replicating the Noah's ark studies in Kannada, a language spoken by some millions of individuals in southwestern India. Kannada differs markedly from English in two relevant ways. First, Kannada licenses much more extensive argument dropping than does English, thus weakening the relationship between argument number and surface noun-phrase number in input speech. Second, it only rarely employs lexical causatives, as in English *sink*, *burn*, and *open*. Transparently enough with regard to principle (a), for many such items English simply adds a noun phrase, rendering "The door opens" as its causative "John opens the door."[11] In contrast, Kannada

[11]The changed word order reflects a different universal bias—namely, to align subject argument with agent semantic role (Keenan, 1976). For a linguistic analysis of causative constructions in English, see Levin and Rappaport Hovav (1995). For emerging knowledge of these constructions in child learners, see Bowerman (1974).

systematically requires, in addition to adding the noun phrase expressing the new role, adding a causative suffix to verbs when and only when causativity is intended. For example, the following (from Lidz & Gleitman, in press) is a Kannada intransitive noncausal usage meaning "The horse rises":

Kudure	eer-utt-ade
horse	*rise-npst-3sn*

To express the causative proposition "The alligator raises the horse" in Kannada, one cannot follow the English model and simply add a noun phrase for the causal agent (in this case, an alligator). That is, the following hypothetical form is ungrammatical:

moSale	kudure-yannu	eer-utt-ade
alligator	*horse-acc*	*rise-npst-3sn*

Rather the causative suffix (-*is*) is also required:

moSale	kudure-yannu	eer-is-utt-ade
alligator	*horse-acc*	*rise-caus-npst-3sn*

One sees this morphological machinery in English (e.g., *lionize* or *elevate*) though sporadically and unsystematically. In short, the two languages differ in their dominant means for expressing the causative version of a predicate.

Surprisingly enough, young Kannada-speaking children who were tested in a Kannada-flavored version of the Noah's ark paradigm assigned causative interpretation to anomalous structures in Kannada as a function of noun-phrase number only (as if they were speakers of English), ignoring the statistically more reliable cue of the presence or absence of the causative morpheme. In contrast, adult Kannada speakers were sensitive to noun-phrase number and the appearance or nonappearance of this morpheme. Lidz et al. drew two related conclusions. First, the young children's behavior reflects the influence of a strong unlearned bias toward the one-to-one alignment principle (a), a bias implicated in early verb learning. Second, the language-particular morphological means of Kannada became linguistic second nature to its expert speakers and so, along with the universal principles, came to play a role in their productive form-to-meaning generalizations.

Syntactic configuration and argument position. Child learners are not limited to the noun-phrase/argument number principle as language-internal evidence for the meaning of verbs. The position of each noun phrase can be highly informative too, especially in languages that, like English, are quite strictly phrase ordered:

(c) The structural position of noun phrases in the clause is related to their thematic role assignment.

We see this principle at work in the spontaneous gesturing of the home signers. In the children's signing, the nouns occurring with each verb do not occur haphazardly to either side of the verb; rather, the children adopt systematic gesture orders, such as routinely signing undergoers immediately before verbs, transitive agents following verbs, and intransitive actors before verbs. Thus, a home signer who produced "snack$_{\langle\text{theme}\rangle}$–eat–Susan$_{\langle\text{agent}\rangle}$" might also produce "Susan$_{\langle\text{actor}\rangle}$–move over" and "cheese$_{\langle\text{theme}\rangle}$–eat" (Goldin-Meadow, 2003b). Apparently, just as no child has to learn to factor experience into predicates and arguments, no child has to learn from some imposed external model to use word order systematically to specify the semantic role played by each element.

However, the ability to exploit surface positional cues to thematic role assignment varies in informativeness and in the specifics of realization across languages. Such cues are most useful, obviously, for languages that are systematically phrase ordered (such as English), less useful in the case of scrambling languages, and perhaps useless in nonconfigural languages. Even for the many languages in which cues from serial order map most transparently onto hierarchical structure, the specifics have to be acquired. Some languages are canonically subject–verb–object, but several other orders occur, including languages in which objects canonically precede subjects. Whatever this ordering, the child must discover it to make the kinds of semantic–syntactic inferences we are now discussing. Notice that the simulated absence of this knowledge shown in the first three bars of Figure 1 (i.e., Nouns, Scenes, and Scenes + Nouns) limits the efficiency of the learning procedure for hard words (15%, 17%, and 30% accuracy scores, respectively). The knowledge enabling the use of syntactic cues to recover the structure of input utterances (in the subsequent four bars) sharply increases that efficiency. In essence, the big issue for the learner in reaching this point is to discover the structural position of the grammatical subject.

Again, unlearned as well as learned factors contribute to this critical step. There is a universal cross-linguistic bias for agent and source semantic roles to capture the grammatical subject position, especially with motion verbs (Baker, 2001a; Dowty, 1991; Keenan, 1976). If this is the learner's expectation—and if he or she understands the nouns *boy* and *ball*—then hearing such sentences as "The boy hit the ball" in the presence of scenes showing a boy hitting a ball will set the subject position for English (as will "The ball hit the boy" and its standard extralinguistic contingencies; and so forth).

Here, we consider studies that demonstrate the special potency of argument position, once established, for disentangling perspective verb pairs, a particularly interesting class of items for understanding the vocabulary learning machinery. Perspective verb pairs include, among many others, *buy/sell, chase/flee,* and *give/get* (see Figure 4 for sample depictions). As these cases illustrate, such pairs describe highly overlapping, if not identical, actions and states of affairs in the observed world. Consider, for example, *chase* and *flee*. Both these predicate the same event. One implies the other. Whenever the hounds are chasing the fox, the fox is fleeing the hounds. If some brave fox turns and makes a stand against its

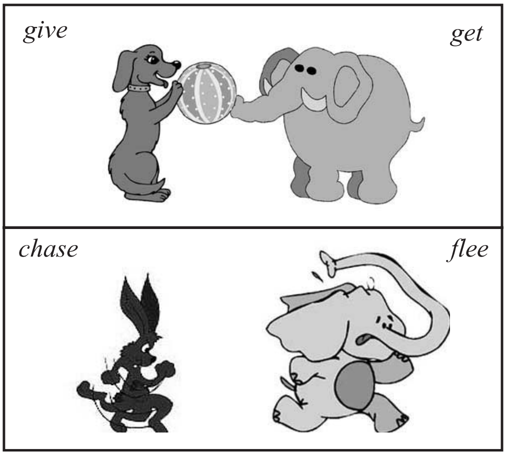

FIGURE 4 Can syntax override the "saliences" of the scene? Cartoon illustrations of two perspective verb-pair events, used in Fisher, Hall, Rakowitz, and Gleitman (1994).

tormentors, it is no longer running away; and in virtue of that, they are no longer chasing him. But if the contingencies for the use of both members of such a pair are the same, then the two cannot be distinguished by Locke's method (1), which requires that such contingencies differ.

Notice that this hunting scenario is not invisible or imperceptible; *chase* and *flee* are not abstract in the senses we discussed earlier. What is different for the two verbs is the speaker's perspective on the (same) event: whether the utterance is *about* the fox or about the hounds. This feature of the predication is invisible. The perspective exists only in the eye of the beholder—in this case, the speaker. To be sure, the two verb meanings encode the two alternative perspective choices, but the question at hand is how the learner discovers which is which if the scene itself is one and the same. Now the syntactic positioning can fill the informational gap. The position of the mentioned participants in the sentence sets their roles as grammatical subject and complement, thereby fixing the meaning of the verb—for example, the rabbit and elephant in the *chase/flee* scene in Figure 4.

Children as young as 3 years (and probably younger) make these syntactic inferences (Fisher et al., 1994). When watching live-action puppet-show events like those illustrated as cartoons in Figure 4, there is a natural tendency to take the source participant, rather than the goal participant in the event as the salient perspective (for discussion of these source–goal asymmetries, see Lakusta & Landau, in press); equivalently, to select the perceived causal agent as sentence subject. For instance, when a scene like that depicted in the second cartoon in Figure 4 is described without syntactic cues (*Oh look, glorping!*), children and adults show a strong preference to think the novel verb means something like 'chase' rather than

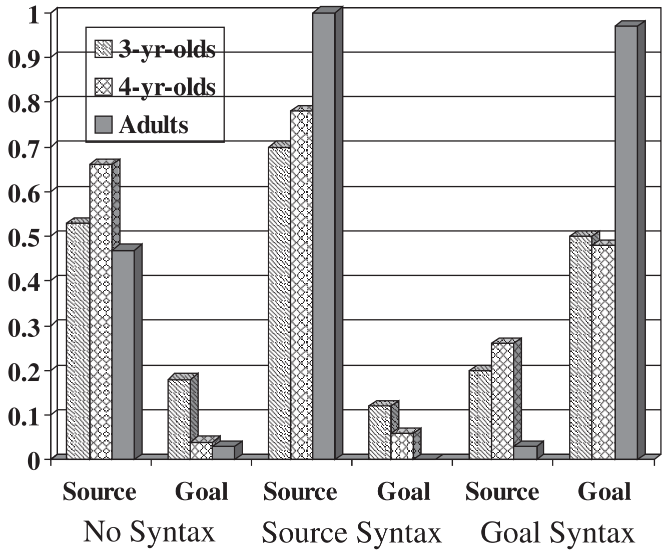

FIGURE 5 Proportion of Source and Goal Subject interpretations by 3-year-olds, 4-year-olds, and adults, as a function of introducing syntactic context. Adapted from Fisher et al. (1994).

'flee.' That is, the causal structure of the event preferentially flows from rabbit instigation to elephant reaction. This preference is substantially enhanced when source syntax is provided (when the scene is linguistically described as *The rabbit is glorping the elephant*). But the preference is reversed to a goal preference when goal syntax is provided (*The elephant is glorping the rabbit*); in that case, children and adults think that *glorp* means 'run away.'

Figure 5 shows Fisher et al.'s effects quantitatively (collapsed across several perspective verb pairs including *chase/flee* and *give/get*, as in Figure 4). As Figure 5 shows, the salience of the source perspective is something that the syntactic configurational evidence must battle against, and it does so fairly successfully but not perfectly (especially for the child participants).[12] This pattern would be expected if the structural configuration chosen by a speaker is indeed used to reflect his or her attentional stance, or perspective. Research on discourse coherence strongly suggests that subject position plays such a role in the transition from one utterance to the next (e.g., Gordon, Grosz, & Gillom, 1993; Walker, Joshi, & Prince, 1997). Subject position is often used to denote the current discourse center. It often marks transitions from one center to another. This is why Fisher et al. described their effect as a "syntactic zoom lens" in which the configuration of the utterance helps the

[12]The proportions here do not add up to 100% in any condition because of the indeterminacy of what can relevantly be said given any observed situation. Thus, in response to one of these scenes, children and even adults sometimes respond, "They're having fun!" or "Look at his hair!" rather than "He's chasing him."

child take the perspective necessary to achieve successful communication and to infer the meaning of unknown elements in an utterance.

As just discussed, because the usefulness of the argument structure cue is heavily dependent on, and interacts with, real-world factors, we now ask whether there are systematic means of communicating or displaying attentional state (i.e., gaze, gesture, posture) such that these may play an informative role in word learning. After all, it is no more reasonable to suppose that lexical learning ignores extralinguistic context than that it is inattentive to the syntactic context. The work of Baldwin (1991) suggests that the child's following of the maternal gaze as a clue to attentional state heavily influences the mapping procedure in the case of nouns. But what about verbs? Can the attentional state of a speaker serve as a cue to verb learning? If so, do young children track these attentional states of speakers to recover their referential intentions? We have begun to explore this question in a series of studies using perspective verb pairs (Nappa, January, Gleitman, & Trueswell, 2004).

For the language learner to be able to use attentional state information as a predictive cue to a speaker's linguistic perspective, a reliable relationship would have to be established between attention–direction patterns and the ensuing linguistic choices. Thus, the first step in this line of research was to establish whether the attentional state of an adult speaker in fact contributes to choice of sentential subject (the one that the description is "about") and hence verb choice. Prior work had suggested that this might be the case (e.g., Forrest, 1996; Tomlin, 1997), but manipulations in these previous studies were often overt, leaving open the possibility that these were laboratory effects—speakers just trying to please the experimenter—and might not characterize more "normal" communicative interactions. We therefore studied this issue again, using subliminal attention-capture manipulations, and we found that we can indeed influence speaker word order and verb choices for the perspective verb pairs. In particular, participants were asked to describe pictures that were designed to elicit perspective verb description (e.g., Figure 6a). From their descriptions, we coded their choice of subject and their choice of verb (e.g., *The dog is chasing …* vs. *The man is running away …*). Crucially, we captured a speaker's attention on a particular character by briefly flashing a square on the computer screen just before the onset of the picture: This square was aligned with the upcoming position of one character or the other; it typically caused eye movements to that character; and it was rarely if ever noticed by the speaker (i.e., a subliminal attention capture). Capturing attention on the chaser in Figure 6a generated *chase* utterances, whereas capturing attention of the flee-er generated increased *run away / flee* utterances (Figure 6b). So, how the speaker "attentionally approaches" an event such as this does seem to affect its description and verb choice.

What about the listener? Can cues to the attentional state of a speaker help in the listener's inference to a verb meaning? Preliminary evidence suggests that this is possible, at least for adults. We modified our task to include a character describing the scene (see Figure 6c), and we asked our participants to "Guess what John is saying." Note that this is quite similar to the task in the HSP: We

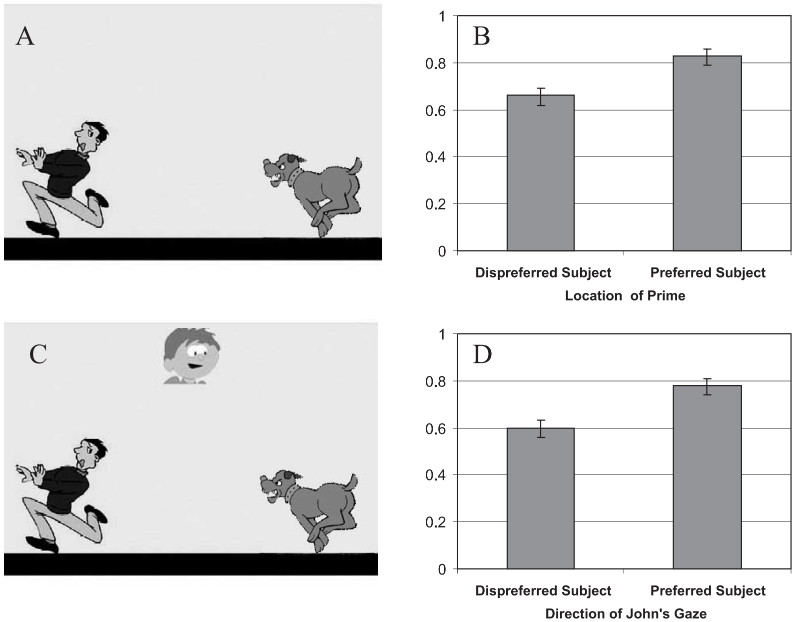

FIGURE 6 Attention, structure, and verb use. Attention capture of a particular participant was accomplished by briefly flashing a square just before presenting a scene (panel A) such that it coincided with the position of a particular character. This attention capture technique influenced the choice of structure and verb use (panel B). The attentional state of a speaker (panel C) had a similar effect (panel D). Preferred subject is defined as the subject that people typically conjecture in unprimed situations. Adapted from Nappa, January, Gleitman, and Trueswell (2004).

were asking participants to guess a verb, this time in the absence of syntactic cues. As can be seen in Figure 6d, verb choice was influenced toward the direction where John was looking: Looking at the flee-er increased the use of *run away / flee*. We are now in the process of assessing whether children can make a similar inference under verb-learning situations. The question is whether, as Baldwin's (1991) studies suggest, the child following his or her mother's gaze in chase–flee scenes will show a bias shift, as the mother does and as our adult participants do in the laboratory. We acknowledge that it is early days to make strong claims in this regard. So we turn next to another kind of hard word, one for which we can provide stronger empirical evidence for the child's convergent use of structural and situational evidence.

Argument type and the acquisition of mental-content verbs. Mental verbs are hard too. Even though children produce verbs describing actions or physical motion early, often before their second birthday (L. Bloom et al., 1975) and appear to understand them well (Gentner, 1978; Huttenlocher, Smiley, & Charney, 1983), they do not use mental verbs as such until they are about 2.5 years old (Bretherton & Beeghly, 1982; Shatz, Wellman, & Silber, 1983), and they do not fully distinguish them from one another in comprehension until around age 4;0 (Johnson & Maratsos, 1977; Moore, Bryant, & Furrow, 1989). For the mental verbs, a new type of structural information becomes important in the inference to meaning:

> (d) The lexical and phrasal composition of arguments is related to the meanings of their predicates.

And in particular:

> (e) Sentence complementation implies a thematic relation between an animate entity and a proposition (semantically, an event or state of affairs).

This relation holds in every known language of the world. The class of items licensing sentence complements includes verbs of communication (e.g., *say, tell, announce,* and Zwicky's nonce verb *greem*), perception (*see, hear, perceive*), and mental acts or states (*believe*, *think, know*); see again Figure 3. To the extent that children can identify it, this syntactic behavior is a useful and principled cue to a novel verb's meaning. Argument type, in conjunction with argument number and position, provides a source of information that systematically cross-classifies the set of verbs within and across languages along lines of broad semantic similarity (Fisher et al., 1991; Geyer, 1994; Gleitman and Fisher, in press; Landau & Gleitman, 1985; Lidz, Gleitman, & Gleitman, 2003b).

As mentioned earlier, adults are sensitive to these regularities in syntax-to-semantics mappings. Furthermore, adults weigh these aspects of language design differently for different verb classes, as the HSP showed (Figure 3). This finding makes sense once one considers the syntactic privileges of the two verb classes. Action verbs are more likely to appear in transitive or simple intransitive frames, which are themselves associated with a broad range of verb meanings. Consequently, these frames provide little constraint on the kind of verb that can appear in them. By contrast, mental verbs often take clausal complements which are more restrictive and hence more informative about the kind of verb that can appear with them (for demonstrations of effects of differential frame informativeness, see Goldberg, 1995; Kako, 1998; Lederer et al., 1995). The HSP studies also showed that, in the case of action verbs, scene information had some measureable efficacy in securing verb identification; however, the same Scenes cue was highly indeterminate for the identification of mental predicates (*think* was hard to acquire by inspecting scenes containing thinkers).

Can children take advantage of argument type in inferring the meanings of new verbs? And how do they coordinate such structural constraints with event representations delivered by observation of the world? Papafragou, Cassidy, and Gleitman (2004) recently set out to investigate these questions by focusing on the vexing class of mental-content predicates, particularly credal verbs, such as *think* or *believe*. The idea here was to compare the contribution of syntactic cues (e.g., sentential complementation) to potentially helpful cues from observation (e.g., the presence of salient mental state, such as a false belief held by an event participant) for the identification of credal verbs.

In this study, adults and 4-year-old children watched a series of videotaped stories with a prerecorded narrative. At the end of each clip, one of the story characters described what happened in the scene, with a sentence in which the verb was replaced by a nonsense word. The participants' task, much as in the HSP, was to identify the meaning of the mystery word. The stories fully crossed type of situation (true vs. false belief) with syntactic frame (transitive frame with direct object vs. clausal *that*-complement). For instance, in one of the false-belief stories inspired by the adventures of Little Red Riding Hood, a boy named Matt brings food to his grandmother (who is actually a big bad cat in disguise). In the true-belief variant of the story, the big cat accompanies Matt as he brings food to his real grandmother. At the end of the story, the cat offers one of these two statements:

> "Did you see that? Matt *gorps* that his grandmother is under the covers!"
> (Complement Clause Condition)
> "Did you see that? Matt *gorps* a basket of food!" (Transitive condition)

It was hypothesized that false-belief situations would increase the salience of belief states and would make such states more probable topics for conversation—thereby promoting mentalistic conjectures for the novel verb. It was also hypothesized that sentential complements would prompt mentalistic interpretations for the target verb. Finally, we predicted that when both types of cues cooperated (i.e., in the false-belief scenes with a sentential complement), the situations would be particularly supportive of mentalistic guesses. Finally, syntactic cues were expected to overwhelm observational biases when the two conflicted (e.g., in false-belief scenes with a transitive frame).

These predictions were borne out. The data showed that scene type had a major effect on the verb guesses produced by both children and adults. Specifically, false-belief scenes increased the percentage of belief verbs guessed by the experimental participants, when compared to true-belief scenes (from 7% to 27% in children's responses and from 24% to 46% in adults' responses). The effects of syntax were even more striking: Transitive frames almost never occurred with belief verbs, whereas complement clauses strongly prompted belief verbs (27% and 66%

of all responses in children and adults, respectively). When both types of supportive cues were present (i.e., in false-belief scenes with complement clause syntax), a substantial proportion (41%) of children's responses and an overwhelming majority (85%) of adults' responses were belief verbs.

Similar effects were obtained in a further experiment with adults, which assessed "pure" effects of syntactic environment (minus supporting content words) in the identification of mental verbs. In that study, true and false belief scenes were paired with transitive or complement clause structures from which all content words had been removed and replaced with nonsense words (e.g., *He glorps the bleep* vs. *He glorps that the bleep glexes*). Again syntax proved a more reliable cue over even the most suggestive extralinguistic contexts; furthermore, the combination of clausal and false-belief scene information resulted in an overwhelming proportion of mental verb guesses.

Taken together, these experiments demonstrate that the syntactic type of a verb's argument (e.g., whether the object of a transitive verb is a noun phrase or a tensed sentence complement) helps word learners narrow their hypotheses about the possible meaning of the verb.[13] Furthermore, this type of syntactic cue interacts overadditively with cues from the extralinguistic environment (e.g., the salience of a mental state). We interpret these findings to support the presence of a learning procedure with three crucial properties: It is sensitive to different types of information in hypothesizing the meaning of novel words; it is especially responsive to the presence of multiple conspiring cues; it especially weights the language-internal cues when faced with unreliable extralinguistic cues to the meaning of the verb (see again Figure 2, for related evidence from HSP).

Remarkably, the workings of this procedure seem much alike in young and more experienced (adult) learners. Both groups show sensitivity to the same kinds of syntactic and situational information, and both groups are able to combine this information in learning novel word meanings in broadly the same ways. To be sure, child participants provide more variable data, but the character of the data set is the same across the age groups. The fact that adults and children are sensitive to the same variables in the same approximate difference magnitudes is unexpected on accounts that attribute children's difficulties with mental and other kinds of meaning to the cognitive immaturity of the learner. It is entirely compatible, however, with proposals that explain the course of early verb learning in terms of the information conditions required to map different kinds of verbs onto their meanings (e.g., Gleitman, 1990; Snedeker & Gleitman, 2004). For mental verbs, the information relevant to identify them resides almost exclusively in their distinctive

[13]Other sources of structural and morphological information (e.g., the type of complementizer in a subordinate clause) place even tighter constraints on verb meaning within the proposition-taking verbs. For instance, you can expect *that someone will come back* but you cannot expect *whether someone will come back* though it is fine to *wonder whether someone will;* you can *insist that someone come* but not *suppose* or *hope that someone come* (rather, you can *suppose* or *hope that someone comes*); and so forth.

syntactic privileges. The unavailability of such information at the early stages of word learning delays the acquisition of mental verbs accordingly.

SUMMARY AND DISCUSSION

We began this article by asking the question, How can children learn the words of their native language? and What is it about natural language vocabulary that allows it to be learned by mere children? We suggested that the answers to these questions are related and point to a learning procedure in which unlearned biases about the mapping of structure onto meaning interact with a learning machinery that integrates across multiple probabilistic sources of input evidence, linguistic and extralinguistic. A key to the evolution of word types over the course of early vocabulary growth has to do with the changing availability of the linguistic cues and their differential potency in cueing different aspects of the lexical stock. As learning begins, the novice's only available cue resides in the ability to interpret the ambient world conceptually and in pragmatically salient ways, matching the lexical formatives with their contingencies of use. This word-to-world pairing procedure sets word learning into motion but is efficient only for certain terms, the so-called concrete ones, especially basic-level object terms. Limited to this kind of evidence, even adults acquire mainly concrete terms, suggesting that the constraint on children too may be more informational than conceptual. Acquisition of abstract items requires the learner to examine the distribution of these known items against one another as a source (among several) of information about the language specifics of the phrase structure. Once the learner has acquired these syntactic facts, he or she can match interpretations of ongoing events and states of affairs with the semantically relevant structures underlying co-occurring utterances, a powerful structure-to-world matching procedure that is efficient across all word types (Figure 1). This improvement in informational resources, rather than changes in the learner's mentality, is what most centrally accounts for the changing character of vocabulary knowledge over the first few years of life, with abstract items acquired relatively late (Figure 2). In sum, lexical learning is *intrinsically* ordered in time, with certain kinds of words necessarily acquired before others, for learning-theoretic reasons rather than conceptual-growth reasons. To learn the verbs efficiently, one needs prior knowledge of a stock of nouns, and one needs to construct linguistic representations that will be revealing of the argument structures intended by the adults who utter them.

We next focused on two kinds of issues concerning the informativenss of structure for lexical learning. The first had to do with how the structure manages to be so efficient as a semantic cue in light of the limited variation among base syntactic structures. The answer was twofold. First, we described the zoom lens hypothesis (Fisher et al., 1994; Gleitman & Wanner, 1982; Landau & Gleitman, 1985): The particular syntactic structure in which a verb appears in the current utterance reveals the argument structure it is currently encoding (Figures 4 and 5). In detail, we showed that the features of argument number, argument position, and argument type are revealing in these regards. The zoom-lens procedure plays the joint function of focusing the listener's attention—rendering different aspects of observed scenes more, or less, salient—and exposing one syntactic–semantic linkage that applies to the specific verb. Thus the role of single structures, while too underspecified to establish any verb's exact meaning, is crucial in narrowing the way that the extralinguistic world itself is to be relevantly parsed. Most strikingly, sentence complement constructions focus the listener's attention on mental aspects of a situation that otherwise are rarely salient to listeners, child or adult (Figure 2).

The second role for syntax in accounting for lexical learning has to do with the information value of the range of a verb's allowed subcategorization (and related) features, taken together. These frame matrices are very sparsely populated (most structures are disallowed for most verbs), and they partition the stock of verbs into rather tight semantic subclasses. Partial overlap of such frame ranges is therefore a powerful predictor of semantic relatedness (Figure 3). As we showed, children and adults efficiently use a verb's observed syntactic range to make quite precise meaning conjectures. Rather remarkably, enough of this range is reflected even in a half-dozen randomly chosen utterances of a mother to her baby that a commendably high accuracy score in identifying them was achieved in the HSP laboratory setting (Figure 1).

As we progressed through this discussion, we emphasized throughout that there is much unpacking to be done in phrases such as "Children … make use of …" and other remarks that have to do with a learning procedure in quite a classical sense. Expectations and biases about language structure and contents ultimately have to make contact with the stream of sounds and the stream of events that confront the novice. Unlearned biases and expectations about the nature of language do not relieve learners from the necessity to acquire the exposure language by inductive inferences of great complexity and subtlety using, among other cues, the evidence of the senses. We tried to show that, for learners to understand how the exposure language realizes these expectations, they need to access an information-processing device that combines, weighs, and integrates across information from different sources (Figure 6).

One important implication of the learning procedure as described is that vocabulary and language-specific syntax are interlocked all along their course. The result is a knowledge representation in which detailed syntactic and semantic information is linked at the level of the lexicon. We do not believe that these lexically specific representations, created in the course of and for the purpose of learning, are dismantled or replaced at some point in life when learning is more or less complete. Rather, the learning procedure leaves its footprint in the mature language design (in related regards, see Osherson & Weinstein, 1982; Pinker, 1984; Wexler & Culicover, 1980; for related but quite different perspectives on how learning may constrain language design, see Elman, 1993; Seidenberg, 1997).

Experimentation on sentence comprehension suggests the continued lexical specificity of linguistic knowledge. This body of findings tells us how detailed probabilistic knowledge about the syntactic behavior of individual verbs pervades the adult language processing system. Native speakers learn not only which sentence structures can grammatically combine with each verb, but also how often each verb occurs in each such structure. Adults retrieve this information as soon as they identify a verb, and they use it to bias online sentence interpretation (e.g., Garnsey, Pearlmutter, Myers, & Lotocky, 1997; Trueswell & Kim, 1998). Snedeker and Trueswell (2004) demonstrated that children and adults resolve the ambiguity of such sentences as *Tickle the frog with the feather* and *Choose the frog with the feather* as a function of the frequency with which these verbs naturally occur with noun-phrase or verb-phrase modification. Thus online parsing decisions by adults and by children as young as 5 years are influenced by detailed and frequency-sensitive knowledge about the syntactic behavior of each verb.

These findings from the psycholinguistic literature mesh naturally with computational approaches to parsing that represent syntactic representations as strongly lexicalized. For example, in Lexicalized Tree Adjoining Grammar, the syntactic possibilities of a language are represented by a finite set of tree structures that are linked with individual lexical items, and a small set of operations by which trees can be joined (e.g., Srinivas & Joshi, 1999). This apparatus permits the statement of syntactic dependencies (such as subcategorization) and semantic dependencies (such as selection restrictions) and yields a natural treatment of noncompositional idioms (*kick the bucket*). Such approaches are based on a claim similar to the one we derived from examination of the learning procedure: An adequate description of the syntactic combinatorial principles of a language is intrinsically entwined with the lexicon and the principles by which it is acquired.

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