LANGUAGE ACQUISITION

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I. Introduction: Outline of the Task

Language learning begins with a perceptual task of startling complexity. Faced with the continuous flow of speech, infants during the first months of life learn about the sound structure of their language, and begin to identify words. A number of intricate problems must be solved along the way, including compensation for many sources of systematic variability in the speech stream. The infant's task is to segment relevant units (of many sizes) from the continuous flow, and store and categorize these – implicitly, of course. The child learning English, for example, must discover that this language is built out of such sound segments as *t, p,* and *a* and that these occur within such larger units as *tap, apt,* and *pat*. This achievement sets the stage for other aspects of language acquisition. Armed with even a few recognizable words, a child can begin to observe how those words are distributed in sentences and relative to communicative contexts. These observations are the primary data for the acquisition of the syntactic and semantic organization of the native language.

Issues of category discovery and labeling arise at every level of linguistic organization. The learner cannot know in advance whether *tap* or *apt* will be permitted sound sequences; whether 'dog' is to be pronounced *dog*, *chien*, or *perro;* which words are nouns (*lightning),* verbs (*flee)* or both (*storm*); how these words are grouped into phrases; whether the subject will precede or follow the verb; or whether word order (rather than case marking morphology) is used to signal semantic roles in sentences. Moreover, not all learners get the same fair shot at data for these discoveries. Owing to pre-existing differences in their life circumstances, children receive systematically differing samples of the exposure language in extralinguistic contexts that also vary. Language learning is not only robust over such environmental differences, it is rapid, accurate, and efficient. As a first indication of this, average children all over the world have acquired a vocabulary of very roughly 10,000 words by the fifth birthday (Carey, 1978); by this age, virtuoso sentences like "Remember the game that you told me last night on the phone you would buy me?" are routine accomplishments.

How do children accomplish this learning? There are three fundamental components of this problem, which structure this review: First, children must find the particular linguistic forms used in their community. Second, they must be able to entertain concepts of the kind that are expressed in languages. Third, they must accomplish a specific mapping between these linguistic elements and the ideas they are used to evoke. Despite this tripartite partitioning of the learning problem for language, its tasks really cannot be separated so simply. Our discussions of the linguistic-formal and conceptual bases of language learning necessarily engage with questions about word and structure-mapping at every level. But in each part of the discussion, we will ask about the learner's initial states. That is, what can children find in the environment, before learning a particular language? The need to understand these primitives is obvious to all commentators, whatever their other theoretical disagreements. In Chomsky's words:

> [O]ne has to try to find the set of primitives which have the empirical property that the child can more or less tell in the data itself whether they apply before it knows the grammar ... So now take grammatical relations, say the notion *subject.* The question is: is it plausible to believe that in the flow of speech, in the noises that are presented, it is possible to pick out something of which one can say: here is the subject? That seems wildly implausible. Rather it seems that somehow you must be able to identify the subject on the basis of other things you've identified, maybe configurational notions which are somehow constructed out of accessible materials or maybe out of semantic notions, which are primitive for the language faculty. (Chomsky, 1982, 118-119)

These primitives, whatever they turn out to be, are part of the human child's endowment for language learning – the set of capacities, mechanisms, and limitations that permit children to find structure in the linguistic input or, if need be, to impose structure on their own invented gestural systems for expressing their ideas. Theories of language learning are distinguished in no small way by what they take these primitives to be, just as are theories of learning in other domains (see chapters by Gelman & Lucariello and by Gould, this volume).

To learn a language is, by definition, to acquire a set of pairings between sounds or more abstract linguistic structures and their meanings. Thus for English it must be learned that the phonological sequence /siy/ is paired with the meaning 'apprehend visually,' for Spanish that it is paired with 'yes,' and for French 'if.' The seven properties of language listed below are basic to language knowledge and use, and so set the minimal agenda that any viable theory of acquisition must answer to.

(1) **Novelty**: Each language provides an infinite set of form-meaning pairings. Therefore, children learn a language "creatively, " developing an understanding of the structure of their language that is abstract enough to produce and understand new sentences.

(2) **Compositionality:** Language accomplishes its unbounded communicative goals without over-running the limitations of memory and categorization by composing each message out of lawfully recombinatory elements at several levels of complexity, arranged hierarchically. The lowest levels in this hierarchy are speech-sound categories and the highest are sentences and discourses. For example, languages decompose unitary events (say, that of a kangaroo jumping) into parts (e.g., the do-er, the action) which then are combined in a sentence ("The kangaroo jumps").

(3) **Expressiveness:** Toddlers bother to learn a language not (or not solely) because of its pleasing formal character but because it is a vehicle supporting the planning and organization of cognitive life, and for communicating with others. Language is meaningful and referential,

expressing no end of messages about the things, stuff, properties, acts, states, processes, relations, and abstractions of which human minds can conceive.

(4) **Sketchiness:** To be useable, language is necessarily sketchy in its conveyance of thought, proceeding in broad brushstrokes, by hints and partial clues. For instance, we refer to a complex observed motion, say of a baseball, with a restricted description of its path and manner of motion, e.g., "He bounced out to third" or "looped one to short left." We make reference by catch-as-catch-can methods, as, the waiter who famously told another that "The ham sandwich wants his check" (Lakoff, 1987). We organize discourse via successive utterances whose interconnections the listener must reconstruct by flights of inference (SHE: "I'm leaving you." HE: "Who *is* he?"; Sperber and Wilson, 1986).

(5) **Ambiguity:** Overt clues to how sentences' parts fit together are often missing or subtle, or unavailable early in the linear transmittal of the sentence. We notice these ambiguities mainly on occasions where the competing outcomes are amusing or bizarre, such as in the ambiguous headlines that linguists use to liven up their classes: *Drunk gets nine months in violin case, Prostitutes appeal to Pope*, or *British left waffles on Falkland Islands* (Pinker, 1994). In most cases, the alternative interpretations that pop up in the course of listening go unnoticed by fluent adults. This points to the next crucial property of language.

(6) **Sociality**: Language use of any kind requires implicit understanding of the goals and intents of others. When a speaker says *I had my car washed,* one must understand plausibilities in the world enough to guess that this was a voluntary act. The same structure is interpreted differently in *I had my car stolen* – but must be *re*interpreted if the speaker is a shady character trying to cheat the insurance company. Words and sentences are used intentionally, symbolically, with the goal of directing another's attention toward the ideas that the speaker has in mind. Therefore some communality, some shared "theory of mind" and shared social context are necessary to get language learning and use off the ground.

(7) **Transmissability**: Language is instantiated in processing systems that allow messages to be transmitted between speaker and listener rapidly and relatively errorlessly. This efficiency of transmission is achieved because the interpretive options made available as the sentence unfolds in time are resolved "on line" by the human listener integrating across several convergent sources of evidence, including situational, lexical, and syntactic (seeTrueswell, Tanenhaus & Garnsey, 1994, among others).

II. Where Learning Begins: Finding Language in the Speech Stream

Faced with the unbroken flow of language use in the environment, infants discover the sound structure of their native language. The analysis of speech is a daunting problem. Every acoustic cue used to identify speech sounds is influenced by many other factors, including the identity of upcoming sounds, overall utterance prosody, speech rate, and even the speaker's voice. Identifying words requires disentangling these interacting sources of information. As we will next see, the infant begins to solve these problems using a formidable capacity for taking in and remembering information about the details and distributions of speech sounds, even before they are assigned any meaning.

Some analysis of speech is logically and temporally prior to the tasks of learning the lexical items and syntactic structures of the language. But learning about sound is by no means irrelevant to other tasks of language acquisition. One connection is obvious—the child's detection of phonological systematicity *creates* the higher-level linguistic units whose distribution relative to one another and to things and events in the world constitutes the primary data for syntactic and semantic learning. In addition, processes involved in the identification of speech sounds interact with other levels of linguistic knowledge. Word identification processes make use of various partially predictive top-down cues to help reduce uncertainty, and the sound patterns of words and utterances play a role (for better and for worse) in the classification of words into grammatical categories and the grouping of linguistic elements in memory (Kelly & Martin, 1994; Morgan & Demuth, 1995). Work in this area provides some of the most compelling evidence for the opportunistic and formal nature of language acquisition: Learners are influenced by multiple types of systematicity in languages, and allow information at one level of linguistic analysis to affect other levels.

A. Categorization of Speech Sounds

1. The Starting Point

Infants are born with a variety of phonetically relevant perceptual capacities. Early in the first year, they readily discriminate speech sounds that fall into different phonetic categories (e.g., discriminating the syllable /ba/ from /pa/), but typically fail to discriminate differences within phonetic categories (e.g., discriminating acoustically different tokens of the syllable /ba/; see Werker & Lalonde, 1988, for a review). The boundaries of young infants' phonetic categories are the same as those commonly found in studies of adult speech perception.

Infants show this sensitivity to phonetic contrasts even for distinctions that are not honored in the language they are learning. Each language's sound system relies on only some of the possible phonetic contrasts; other possible phonetic distinctions are ignored, not used *contrastively* to differentiate words in the language. For example, Hindi distinguishes two t-like sounds, a dental [t] and a retroflex [T]. In English, both of these sounds are heard as instances of the same category /t/, and English-speaking adults have difficulty discriminating the two. English-listening 8-month-olds, on the other hand, readily discriminate the dental and retroflex /t/s (Werker & Lalonde, 1988; see Eimas, 1975; Trehub, 1976; Werker & Tees, 1984, for related findings). Infants' ability to discriminate categories not used contrastively in their languages, and not reliably controlled by their parents, tells us that these speech sound categories are a built-in part of the auditory perceptual capacities of the infant. The initial set of phonetic categories is not unique to humans: Other mammals, including chinchillas and macaques (Kuhl & Miller, 1975; Kuhl & Padden, 1982, 1983), exhibit the same peaks of discriminability along dimensions of phonetically-relevant variation. Human languages are made out of the perceptual categories that young humans (and other mammals) find easy to discriminate.

2. Effects of Language Experience

Language experience reduces the set of phonetic distinctions to those used contrastively in a particular language. By 10 to 12 months infants' ability to discriminate non-native contrasts is sharply reduced (Werker & Tees, 1984)[1]. In a few short months, infants redirect their attention to contrasts relevant to their native language phonology (Jusczyk, 1997; Liberman, Harris, Hoffman, & Griffith, 1957; Pisoni, Lively, & Logan, 1994). A traditional assumption is that semantic learning could drive this reorganization: Infants could learn to ignore phonetic differences that do not signal meaning differences (e.g., Bloomfield, 1933), using pairs of words that differ minimally in sound but contrast in meaning (*bear/pear, rent/lent*) to determine the phonemic inventory of their native language. This notion has some initial plausibility, since infants begin to attach meanings to some words before their first birthdays.

However, there are reasons to believe that semantic learning is not the initial force that drives the creation of phonological categories. First, though it is hard to estimate infant comprehension vocabularies, it seems unlikely that the word comprehension skills of 10-month-olds are sufficient to fix the phonemic inventory of their language in such a short time. Word recognition is hard, and young listeners are notoriously prone to error (Gerken, Murphy, & Aslin, 1995; Stager & Werker, 1997); yet infants uniformly move to a language-specific pattern in consonant perception between 10 and 12 months of age. Second, some migrations toward native-language targets happen before infants learn the meanings of any words. Kuhl, Williams, Lacerda, Stevens, and Lindblom (1992) found that 6-month-olds learning English and Swedish showed systematically different patterns of discrimination among synthetic vowels, and that these differences were predictable from English and Swedish speakers' judgments of vowel typicality. Such an early effect of language experience suggests that pre-semantic perceptual learning changes the child's phonetic inventory. Third, the adult consonant inventory is not simply a subset of the infant's. Languages differ not only in which of a built-in set of possible speech sounds are contrastive in their phonologies, but also in the detailed phonetic realization of each category (Farnetani, 1997; Keating, 1985; Lisker & Abramson, 1964; Pierrehumbert, 1990). Learning a language's phonological categories involves adjusting the weighting of various acoustic cues and the boundaries between phonetic categories to coincide with the category structure used by its speakers. These considerations suggest that the discovery of native-language phonology relies heavily on perceptual learning about native language sounds, without early feedback from the semantic system. Kellman (this volume) argues that much perceptual learning across domains occurs as a result of simple exposure, requiring no feedback.

3. The Role of Distributional Information

What information, other than word meaning, could drive the change in speech sound categorization? It might be that infants could learn about the functional significance of various sound properties by observing their distribution in the speech they hear, without initial recourse to meaning. This could happen in at least two ways.

First, consonant and vowel tokens in different languages differ in their distributions along various acoustic dimensions. Sounds common in some languages are rare in others, and areas of the phonetic space in which different languages make different numbers of distinctions (e.g., one category versus two or three) will differ correspondingly in whether speech sound tokens cluster

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[1] The irrelevant contrasts are not entirely destroyed: Adults are not completely hopeless at re-learning non-native contrasts when acquiring a second language, though they rarely achieve native competence in discriminating them (e.g., Pisoni, Aslin, Perey, Hennessy, 1982).

around one, two, or three frequency modes (Lisker & Abramson, 1964). Infants listening to different languages thus hear different distributions of acoustic tokens; this information could help to redistribute their attention within the phonetic perceptual space (e.g., Guenther & Gjaja, 1996; Jusczyk, 1997; Kuhl, 1994; Maye & Gerken, 2000).

Second, sounds that are not contrastive can be defined, not only as those never used to differentiate semantically distinct words, but also as phonetically similar sounds that occur in *complementary distributions* in the language being learned (e.g., Chomsky & Halle, 1968). Such sounds become *allophones* of the same language-specific phonemic category. For example, in English we do not use nasal and non-nasal vowels contrastively (though other languages do). Instead, vowel nasalization in English is predictable from context. Vowels preceding nasal consonants (e.g., the /i/ in *bean*) are nasalized, and vowels in other contexts are not (e.g., the /i/ in *bead*). Vowel nasalization is not contrastive in English, since its occurrence is redundant with a following nasal consonant. Systematic phonetic variation which is not contextually predictable is contrastive in the language being learned. Distributional learning—about what sounds occur frequently in one's language and where they occur—is thus directly relevant to the categorization of speech sounds (Guenther & Gjaja, 1996; Jusczyk, 1997; Kuhl & Meltzoff, 1996; Lotto, 2000; McClelland & Elman, 1986; Werker & Tees, 1999).

More generally, the *phonotactic* patterns that describe how speech sounds can be ordered in a particular language interact with speech sound categorization. For example, in English, words never begin with the sequence /tl/, though it occurs elsewhere (e.g., *little*). By 9 months, English-listening infants prefer to listen to sequences of unknown words from their own language than to Dutch words that violate the phonotactic rules of English (Jusczyk, Friederici, Wessels, Svenkerud, & Jusczyk, 1993; see also Friederici & Wessels, 1993). Infants also pick up phonotactic regularities less absolute than the proscription of initial /tl/ in English: By 9 months they listen longer to made-up words with frequent rather than infrequent (though legal) sequences of segments (Jusczyk, Luce, & Charles-Luce, 1994). The language processing system remains sensitive to phonotactic probabilities throughout life; thus adults pick up new sequencing regularities through speaking practice (Dell, Reed, Adams, & Meyer, 2000) or listening practice (Chambers & Onishi, 2001).

Adults use phonotactic patterns to help identify speech sounds. Since /tl/ never begins English words, for example, a sound ambiguous between an /l/ and an /r/ will be heard as an /r/ if it follows an initial /t/ (e.g., Elman & McClelland, 1988). Given a highly constraining context, listeners hear sounds with no acoustic basis at all; this includes the phoneme restoration effect that allows us to interpret white noise as a consonant in the context of a familiar word (Samuels, 1997). Such context effects characterize language processing systems at every level of linguistic analysis: Wherever possible, information about how elements are combined into higher-level units plays a role in the identification of those elements. As infants acquire the phonotactic regularities of a language, knowledge of what sequences are possible or frequent should influence their ability to identify speech sounds. Top-down effects on perceptual identification accuracy are not unique to human speech perception. Perceptual category-learning in many domains affects our perception of the categorized objects: Objects in the same category are judged more similar; objects in different categories are judged less similar, whether the stimuli are faces, nonsense objects, or speech sounds (Goldstone, Lippa, & Shiffrin, 2001; Kellman, this volume).

B. Segmentation and Spoken Word Identification

The foregoing discussion of distributional learning about speech has already invoked higher-level linguistic units. Phonotactic regularities depend on position in syllables and words, for example. This suggests the kind of chicken-and-egg learning problem that plagues every area of language acquisition: To learn the phoneme categories, infants must learn about the distributions of phonetically-relevant sounds; to learn the relevant distributional facts, infants must identify the boundaries of syllables and words. But how could anybody identify words without having a phoneme inventory to begin with? Where do these units come from?

1. The Starting Point

Segmentation of continuous speech into any sort of units is more problematic than it might seem. Even the syllable is not acoustically well defined (see Brent & Cartwright, 1996; Eimas, 1999; Lass, 1984; Vroomen, van den Bosch, & de Gelder,1998). Vowels have more acoustic energy (i.e., are louder) than consonants, and this profile creates a salient alternation between high- and low-energy sounds in speech. The difficulty lies in how to syllabify consonants at the edges of syllables. Different languages have different rules about where syllable boundaries fall. Sub-lexical units like the syllable also play different roles in the online processing of different languages by adults, depending on the rhythmic structure of the language (Cutler, Mehler, Norris, & Segui, 1986). The real perceptual obscurity of syllable boundaries can be seen in word-perception errors that sometimes violate the presumed boundaries of syllables (as in “This guy is falling” heard instead of “The sky is falling”).

Despite the perceptual pitfalls and cross-linguistic variability of syllabification, it is likely that something like the syllable is a fundamental unit of speech perception for young infants. This conclusion is based partly on failures to find evidence of segmentation into smaller, phoneme-like units (Eimas, 1999; Mehler, Segui, & Frauenfelder, 1981; Jusczyk, 1997), but also on evidence that newborn infants categorize speech sequences by syllable number (e.g., 2 versus 3; Bijeljac-Babic, Bertoncini, & Mehler, 1993), stress pattern (Sansavini, Bertoncini, & Giovanelli, 1997), and shared syllables (Eimas, 1999; Jusczyk, Jusczyk, Kennedy, Schomberg, & Koenig, 1995). Infants’ representations of speech contain information that allows them to detect its rhythmic structure. Finding the edges of syllables may depend on language-specific phonotactic learning (Brent & Cartwright, 1996; Church, 1987; Vroomen et al., 1998; Smith & Pitt, 1999).

2. Finding Words

The perceptual problems involved in finding words have been canvassed many times. Spoken words are not separated by silences or other obvious cues to their boundaries, as written words are separated by white spaces on the page. There are some cues to the location of word boundaries, including word-position effects on the duration of segments (Klatt, 1976), allophonic variations unique to word or syllable beginnings or endings (Gow & Gordon, 1995; Jusczyk, 1997; Nakatani & Dukes, 1977), stress patterns (Cutler, 1990), and the phonotactic regularities discussed above. These pre-lexical cues are language-specific; thus they have to be learned. Even once learned, moreover, such cues leave considerable ambiguity about the location of word boundaries. For this reason, theories of adult spoken word recognition typically assume that identification of word boundaries is in part a result of the identification of a familiar word, rather than a prerequisite to it (Lively, Pisoni, & Goldinger, 1994).

Distributional evidence for word boundaries. Evidence now suggests that infants, like adults, may identify word boundaries by recognizing words as familiar sound sequences. Eight-month-olds listened to an uninterrupted sequence of nonsense syllables constructed by randomly concatenating four nonsense words (e.g., *bidakupadotigolabubidaku...;* Saffran, Aslin, & Newport, 1996). The stimuli were presented with no pauses or variations in stress, so as to offer no clues to word boundaries other than the high transitional probability linking syllables within but not across word boundaries. In test trials, infants heard words from this artificial language on some trials, and "part-words" on other trials. Part-words were sequences that had occurred during the familiarization phase, by chance concatenation of the four words that formed the basis of the training language. Infants listened longer to the relatively novel part-words. Later experiments controlled the frequency of word and part-word test items, to ensure that transitional probability, and not simple frequency, was responsible for infants' preference for part-words (Aslin, Saffran & Newport, 1998). These findings are akin to the use of kinetic cues in segmenting coherent objects in the visual world: An object whose parts move together against a variable background is readily perceived as a single object (e.g., Kellman & Spelke, 1983). Similarly, the infants in these listening experiments detected repeating sequences whose syllabic parts remained in the same relationship to one another across different speech contexts.

This ability to pick up on contingencies in the input is specific neither to language nor to human learning: Infants show the same ability to learn sequential patterns among musical notes (Saffran, Johnson, Aslin, & Newport, 1999), and tamarin monkeys carve internally coherent "words" from a stream of syllables (Hauser, Newport, & Aslin, 2001). Younger infants, however, are probably unable to find words as repeating sound patterns in the speech stream: 7.5-month-olds, but not younger infants, preferred to listen to isolated words that they recently heard presented in connected speech, over words not recently presented (Jusczyk & Aslin, 1995). Six-month-olds also show no sensitivity to the phonotactic regularities of their native language (Jusczyk et al., 1995). Such findings suggest that the ability to identify and remember a sequence of phonological segments—well enough to identify a word—does not become reliable until after 7 months of age.

Rhythmic cues for word segmentation. Despite their inability to reliably recognize particular sequences of phonemes or syllables, younger infants are not at a loss to detect familiar units of any kind when presented with continuous speech. Six-month-olds use consistent metrical or rhythmic patterns in speech to create coherent word-like units (Morgan & Saffran, 1995; Morgan, 1996). Six- and 9-month-old infants were trained to turn their heads whenever they heard a buzz, to catch sight of a visual reward. These buzzes were presented against a background of syllable sequences varying in segmental consistency and stress pattern. Six-month-olds were slower to detect the buzzes if they interrupted two-syllable sequences presented with a consistent trochaic (strong-weak, as in *baby*) or iambic (weak-strong, as in *delay*) stress pattern than if the buzzes occurred at the boundaries of such units. This was true even if the syllables picked out by the consistent pattern varied in their order (e.g., KOgati ... GAkoti ...); 9-month-olds required both consistent ordering and consistent stress to hear these nonsense syllables as a word-like, uninterruptible unit. Before they can reliably identify and remember a sequence of phonemes, infants can hear a repeating stress pattern. This rough analysis of the speech stream would provide infants with some starting units that could make possible a finer-grained analysis of words.

Infants quickly pick up the typical stress patterns of words in their language. By 9 months, infants have figured out that strong syllables tend to begin words in English, and therefore prefer to listen to sets of unfamiliar words with a strong-weak stress pattern rather than a weak-strong pattern (Jusczyk, Cutler, & Redanz, 1993), and find novel trochaic bisyllables more cohesive in the buzz-detection task mentioned above (Morgan, 1996). Infants 7.5 months old are better able to detect words in continuous speech if the words have a strong-weak stress pattern, and they can be fooled by chance repetitions of adjacent strong and weak syllables that happen not to constitute a word (Jusczyk, 1997). The advantage for strong-weak words in word-detection experiments suggests that infants use their knowledge of the frequency of strong-weak bisyllabic words in English as a heuristic to find new words. This is the metrical segmentation strategy proposed by Cutler (1990) as a bias in English word identification. Early input would support this heuristic: Investigations of spontaneous child-directed speech show that the vast majority of bisyllabic English words have a trochaic stress pattern (Morgan, 1996; Swingley, 2000).

Phonotactic cues to word boundaries**.** By 9 months, infants use phonotactic regularities to help carve words out of continuous speech. For example, the consonant sequence /ft/ occurs relatively frequently within English words (e.g., *lift, after*); /vt/ is rare within words, but common across word boundaries (e.g., *love to)*. Mattys and Jusczyk (2001) embedded nonsense words in texts so that their edges were marked by phonotactic sequences either common within words (therefore bad for word segmentation) or rare within words (therefore good for word segmentation). Nine-month-olds detected the words, later showing a listening preference for the familiarized nonwords presented in isolation, only if the new words were edged with good phonotactic word segmentation cues. Infants, like adults (McQueen, 1998) use phonotactic rules and probabilities in word segmentation.

How do infants learn about phonotactic regularities? One possibility is that they learn which sound sequences can begin and end words by observing what sound sequences begin and end whole utterances (Brent & Cartwright, 1996). As we next discuss, utterance boundaries are well marked by reliable prosodic cues; these boundaries display many (though not all) of the possible word onsets and offsets. Another possibility is that infants detect regularities in the sound patterns of words or syllables by detecting repeating sequences of phonemes, just as by 8 months they can detect repeating sequences of syllables.

Summary: Multiple Constraints**.** The picture that emerges is one of a perceptual learning process sensitive to interacting distributional regularities at many levels of analysis. Infants detect and make use of a variety of probabilistic cues that make some analyses of a speech sequence into words more likely than others. These cues include the internal consistency of phoneme or syllable sequences within familiar words, the typical stress patterns of native language words, and probabilistic phonotactic regularities.

C. The Role of Sound in Syntactic Analysis

As soon as some words can be identified, children can begin learning how those words are used, both syntactically (how they are distributed with respect to other words and phrases) and semantically (how they function to convey meaning). These facts feed back into the word identification process, allowing word selection to profit from knowledge of semantic and syntactic constraints. In this section we will see that the sound patterns of words and phrases are relevant to syntactic processing as well. Just as English-learning infants (and adults) find it easier to identify the boundaries of bisyllabic words with a trochaic (strong-weak) than with an iambic (weak-strong) metrical pattern, sound pattern information contributes probabilistically to the identification of a word's grammatical category and the grouping of words within phrases and clauses.

1. Prosodic Bootstrapping

Utterances have a characteristic rhythmic and intonational structure known as prosodic structure. Prosodic phonology proposes a hierarchy of phonological units (e.g., utterances, phrases, words) that define the domains of phonological rules (Selkirk, 1984). These prosodic units tend to correspond to syntactic units. The prosodic bootstrapping hypothesis proposes that infants' perception of the familiar rhythmic and intonational structure of phrases and utterances in their language guides analysis of the syntax of the native language (Gleitman & Wanner, 1982; Gleitman, Gleitman, Landau, & Wanner, 1988; Morgan, 1986; Morgan & Demuth, 1995; Morgan & Newport, 1981; Morgan, Meier, & Newport, 1987).

Acoustic bracketing of the utterance. The usefulness of prosodic bracketing of speech is most obvious at the level of the whole utterance. The boundaries of utterances are well marked by salient acoustic cues, both in adult- and infant-directed speech. In adult-directed English, words tend to be lengthened at the ends of utterances or major phrases (Cooper & Paccia-Cooper, 1980; Klatt, 1976), pitch tends to fall near the end of an utterance (Cooper & Sorenson, 1977), and pauses occur at utterance or major phrase boundaries (Gee & Grosjean, 1983; Scott, 1982). The same kinds of features are readily measured in spontaneous speech to infants (Bernstein Ratner, 1986; Fisher & Tokura, 1996; Morgan, 1986). These acoustic properties help utterances to cohere as perceptual units for adult listeners. Lengthening and pitch changes cause adults to perceive a subjective pause in speech in the absence of a silent pause (Duez, 1993; Wightman, Shattuck-Hufnagel, Ostendorf, & Price, 1992), and can disambiguate syntactically ambiguous sentences (Beach, 1991; Klatt, 1976; Lehiste, 1973; Scott, 1982; Kjelgaard & Speer, 1999).

Infants are also sensitive to these prosodic contours: 6- to 9-month-olds listened longer to samples of infant-directed speech with pauses inserted at sentence boundaries rather than within these constituents (Hirsh-Pasek et al., 1987; Kemler-Nelson, Hirsh-Pasek, Jusczyk, & Wright-Cassidy, 1989). Apparently infants detect pitch and timing changes that predict upcoming pauses, and pauses not preceded by these changes sound unnatural to them. In a habituation task, 2-month-olds were better able to remember the phonetic content of words produced as a single utterance than of the same words produced in a list or as two sentence fragments (Mandel, Jusczyk & Kemler-Nelson, 1994; Mandel, Kemler-Nelson, & Jusczyk, 1996). The familiar rhythm and melody of utterances helps infants to organize speech in memory, serving the perceptual grouping function proposed by Morgan et al. (1987).

Acoustic bracketing of phrases within utterances. Can prosody hint at the boundaries of within-utterance phrases? Evidence suggests it can, but also suggests important limitations on prosody as a source of information about syntactic structure. Sentences in speech to infants and toddlers are short (Newport, Gleitman, & Gleitman, 1977; Snow, 1972), and so offer few opportunities for clear acoustic markings of within-utterance phrase boundaries. But where there are multiple syllables preceding a major phrase boundary, some acoustic cues to boundary location can be detected (Fisher & Tokura, 1996; Gerken, Jusczyk, & Mandel, 1994). Infants are sensitive to these subtle within-sentence cues as well as to the grosser prosodic patterns that group words into utterances. In several studies, 9-month-olds listened longer to sentences with pauses inserted between the subject and the verb phrase than to sentences with pauses inserted after the verb (Jusczyk, Hirsh-Pasek, Kemler-Nelson, Kennedy, Woodward, & Piwoz, 1992; Gerken et al., 1994), though only when these sentences had relatively long, full noun phrase subjects (*the caterpillar*; see also Read & Schreiber, 1982).

The discovery of prosody and syntax. A number of problems arise in developing an account of the role of prosody in early syntactic analysis of input speech. The first is that prosody and syntax don't always coincide, and some syntactic boundaries have no prosodic marking at all. This suggests that prosody can serve only as one among many kinds of data that could guide analysis of linguistic elements. As Morgan et al. (1987) suggested, prosodic contours could help to group elements within likely syntactic boundaries, but so could concord morphology, which places rhyming affixes on words within a phrase (e.g., *los niños pequeños*), and so could semantic information (e.g., if *red* is true of the *cup*, then the two words are probably in the same phrase; Pinker, 1984). The second problem is the discovery of prosody itself. Prosodic structure is abstract, and its identification based on acoustic properties of sentences is knowledge-driven enough to complicate its role as a "bottom-up" cue to other levels of linguistic structure. The very same features of duration, pitch, and amplitude of syllables that are used to identify prosodic structure are also affected by particular segments and words, and by the idiosyncrasies and emotional state of the speaker (Fisher & Tokura, 1996). The acoustic expression of prosodic structure also varies across languages. Infants therefore must develop quantitative estimates of the acoustic shape of utterances and phrases in their own language.

How might this work? Infants pick up abstract rhythmic properties of speech very readily. Newborns can discriminate sets of sentences spoken in different languages (Mehler et al. 1988; Nazzi, Bertoncini, & Mehler, 1998). This ability is based on a sensitivity to the rhythmic basis of speech, even in languages the infants have never heard before. Languages can be classified in terms of their basic unit of timing: English and Dutch are stress-timed languages, characterized by alternation between strong and weak syllables, with a (rough) tendency to equate intervals between stressed syllables. Other language classes select different units to mete out the regular timing of sentences. Japanese is mora-timed (morae are sub-syllabic units), and Spanish and French are syllable-timed. Nazzi et al. (1998) habituated newborn infants to samples of speech in one of two unfamiliar languages, and found that they could detect a change to the other language only if the two differed in their fundamental rhythmic basis. Ramus, Nespor, and Mehler (1999) found that stress-, syllable-, and mora-timed languages differed categorically along a dimension defined by the proportion of each utterance devoted to vowels.

This phonetic dimension could be used to predict language discrimination by newborn infants. Other factors such as variability in vowel duration across utterances may permit more detailed prediction of the perception of linguistic rhythm. Robust sensitivity to rhythmic structure is also found in adult's and infants' perception of music (Trehub, 1987), even though music, like speech, provides only very complex evidence for a regular beat.

Infants become able to discriminate their own language from another language in the same rhythmic class by 4 or 5 months of age (American vs. British English; Nazzi, Jusczyk, & Johnson, 2000; Spanish and Catalan; Bosch & Sebastian-Galles, 1997). Given the tender age of these listeners, it is most likely that this new ability is due to learning about prosody rather than phonotactic structure or recognizing particular words. Consistent with this possibility, the Spanish- (or Catalan-) -listening 4-month-olds could still tell those two languages apart when the materials were filtered to hide such details; the result sounds much like the muffled speech one sometimes hears through the hotel room walls (Bosch & Sebastian-Galles, 1997).

2. The Coincidence of Sound and Grammatical Category

Words within grammatical categories tend to share phonological similarity, and both adults and children use this information in categorizing words (e.g., Kelly, 1992; Kelly & Martin, 1994). One of the most obvious differences is the phonological distinction between open-class or content words (the nouns, verbs, adjectives) and the closed-class or function words (affixes, determiners, etc.). Because function words provide major clues to boundaries between phrases, being able to recognize them by their sound patterns would aid the discovery of syntactic structure. Across languages, content and function words differ in way that would support such a procedure -- in all the acoustic correlates of stress (duration, pitch change, amplitude), in syllable weight (function words possess minimal syllable structures and short vowels), and their positions in phrases (function words tend to appear at phrase edges). These two clusters of correlated phonological properties permit a very accurate division of words into content and function word sets (Shi, Morgan, & Allopenna, 1998). The phonological difference between these two sets is so large that even newborns can categorize words this way, re-orienting to sets of content words after habituating to isolated function words, and the reverse (Shi, Werker, & Morgan, 1999).

Surprisingly, there are also probabilistic phonological differences between syntactic categories of content words, though these are specific to particular languages. English nouns tend to have more syllables than verbs. Even though most words in English (nouns and verbs alike) have first-syllable stress, this generalization is much stronger for nouns than for verbs. Adults are more likely to identify a nonsense word as a verb than a noun if it has the second-syllable stress (Kelly, 1988; 1992). Similar effects have been shown for 3-year-olds (Wright-Cassidy & Kelly, 1991). Such phonological similarities within grammatical categories are common across languages (Kelly, 1992), and may support the discovery of these categories during acquisition.

D. Distributional Analysis and the Discovery of Syntax

Though phonological similarity influences syntactic categorization, these sound-organizational properties are partial and probabilistic, and vary across languages. Similarly, semantic evidence for word classification is also probabilistic (why is *thunder* but not *lightning* a verb?) and enormously abstract – though our teachers said that a noun was "a person, place, or thing" it was no great trick to find counterexamples (*fun, mile, thought, nothing, green*). For these familiar reasons, every theory of grammar acquisition presumes that children put their money primarily on a more reliable data base: Different kinds of words are distributed differently across the sentence. We already saw that young infants efficiently extract the patterned distribution of syllable types in nonsense sequences like "*bidakupadoti* …"; presumably this laboratory demonstration is related to the way infants segment continuous speech into words, in real life. Now we will see such a procedure repeat itself at the next linguistic level: A formal analysis of the relative distribution of linguistic forms yields their classification as nouns, verbs, and so forth, and thus is fundamental to syntax acquisition.

The most familiar modern statement of a distributional learning algorithm for grammatical categories is from Maratsos and Chalkley (1980). Following structural linguists like Bloomfield (1933) and Harris (1951), they proposed that children could sort words into grammatical categories by noting their co-occurrences with other morphemes and their privileges of occurrence in sentences. *Morphemes* include words and smaller meaningful elements that attach to words (e.g., the English past tense -*ed*). Nouns and verbs occur with different classes of function morphemes (*the, a, -s* versus *is, will, -ing, -ed*); noun phrases serve as subjects of sentences and objects of various predicates (the verbs, the prepositions). Maratsos and Chalkley's (1980; see also Maratsos; 1998) original argument for the necessity and power of distributional analysis in the acquisition of grammatical categories and phrase structure was based on the existence of the meaningless or nearly meaningless grammatical gender classes within the category noun. The distinction between masculine and feminine nouns in many languages is notorious for its lack of a reasonable semantic basis; what makes a noun "feminine" is its co-occurrence with feminine determiners, case markers, and agreement markers on adjectives and verbs. Thus the existence and extension of these categories must be acquired via an analysis that detects these predictive dependencies. Children learn the grammatical gender classes at about the same rate that they pick up other grammatical categories in their language. Why not distributional learning, all the way down?

Many reviews of the field of language acquisition since Maratsos and Chalkley's work was published were skeptical. Several commentators (Gleitman & Wanner, 1982; Pinker, 1984) objected that the useful correlations relied on in Maratsos and Chalkley's analysis were between open-class (nouns, verbs, adjectives) and closed-class items (determiners, tense, case, or agreement markers). Function morphology is conspicuously lacking in young children's language use (R. Brown, 1973). If children are late to discover function morphology, it would seem perilous to build an initial acquisition procedure on the distribution of function morphemes. In addition, the procedure seemed too unconstrained. How would children ever find the useful dependencies between open- and closed-class morphemes amid the unbounded set of irrelevant or misleading co-occurrences they might track? The empirical foundation of theories of language acquisition has changed in some fundamental ways in the past twenty years, robbing these objections of much of their force. First, as we showed earlier, the content-word/function-word distinction can be discovered by noting the differing phonological properties characteristic of these classes (Shi et al., 1998, 1999). Second, there is now evidence that very young children are sensitive to the distribution of function morphemes, in the way required. Gerken, Landau and Remez (1990) found that young 2-year-olds, when asked to imitate long sequences of real and nonsense words, omitted real function words more often than unstressed nonsense syllables. The selective preservation of unfamiliar unstressed syllables suggested that these toddlers knew more about the sound patterns and distribution of function words than their own speech would suggest. Gerken & McIntosh (1993) also showed that two-year-olds more accurately comprehended familiar nouns preceded by grammatical (*the bird*) rather than ungrammatical (*was bird*) function words (see also Santelmann & Jusczyk, 1998 for related findings with verb phrase morphology in 18-month-olds). These studies do not exhaust what we need to know about young children's detection and use of function morphology in language comprehension, or their use of dependencies among words to construct grammatical categories and build phrase structure; but they put our theories of the role of distributional analysis in early syntax acquisition on a very different empirical footing

There was a final objection to distributional analysis as a foundation for category discovery and syntax acquisition (Wanner & Gleitman, 1982; Pinker, 1984, 1987), which can still be found in the introductions of papers that take a more optimistic stance toward distributional analysis by infants (e.g., Cartwright & Brent, 1997; Mintz, Newport, & Bever, 1995): Strings of morphemes are full of ambiguity. Nouns occur with a plural *–s*, but verbs occur with a second-person present-tense singular *–s*. Active verbs take the progressive ending *–ing*, but verbs so marked can be used as adjectives (*astonishing*) or as nouns (*Jogging exhausts Bill.*) The English morpheme *–ed* has the same fate, often marking verbs (e.g., *admired, hot-footed)* but also marking attributive adjectives that are not verbs at all (*redheaded, light-fingered, widely-admired*). Sentence templates pose the same problem: the sentences *I like fish* and *I can fish* form a distributional minimal pair that might falsely license the categorization of *like* and *can* as the same sort of word.

The status of this objection, twenty years later, is still unclear. Such examples tell us that the distributional analysis carried out by language learners must be a protracted process of integrating multiple predictive dependencies across many sentences, bolstered by the semantic cues that are part of every theory of syntax acquisition, and by phonological grouping and within-category similarity, and strongly influenced by progress in morpheme segmentation. Chiefly through research on infant learning of phonology, the field has gained a greater respect for the statistical learning abilities of young infants, and the wealth of detail learners can hold in memory and bring to bear on new experience. The preschoolers who show instance-specific as well as abstract long-term priming for the sounds of new words (Fisher, Chambers, Hunt, & Church, in press), the 10-month-olds who recognize a particular musical performance (Palmer, Jungers, & Jusczyk, in press), the 9-month-olds who are sensitive to the phonotactic probabilities of the native language (Jusczyk et al., 1994), and the 8-month-olds who learn words based only on transitional probabilities (Aslin et al., 1998), are clearly no slouches when it comes to taking in, remembering, and abstracting over huge quantities of data.

Computational work on distributional learning has begun to examine explicit models of how distributional analysis of linguistic forms might work. The general finding is that fairly simple assumptions and algorithms can go some distance toward sorting words into grammatical categories, even unaided by semantic and phonological cues. For example, Cartwright and Brent (1997) generalized the notion of sentential minimal pairs (as in the misleading example above, but also *That's a cat* and *That's a cup*) to produce a distributional learning algorithm that groups words based on appearance in similar templates. The algorithm seeks the most compact description of the input sentences in terms of few, short, and frequent sentence templates, and few, uniform word groups. Simulations demonstrated that, assuming pre-existing knowledge only of word boundaries, co-occurrences of sets of words provide considerable information about grammatical categories. Mintz et al. (1995) clustered together words based on similarity in distributional context defined as the preceding and following word. They found that this restricted analysis of co-occurrence among words yielded a similarity space that permitted good separation of nouns and verbs. Similar results were obtained when unstressed monosyllabic function words (e.g., *a, the, is*) were left out of the analysis altogether, or all treated as an undifferentiated weak syllable. These computational analyses and simulations lead to an important class of conclusions: on various sets of simple assumptions, a tractable analysis of the probabilistic distributional patterns in language can provide a bootstrap for the discovery of the linguistic category structure that produced those patterns (see also Redington, Chater, & Finch, 1998). Similar arguments are made for the discovery of morphology: for example, Goldsmith (2001) proposed an algorithm that learns a probabilistic morphological system from text input, dividing words into roots and affixes so as to minimize the number, and maximize the frequency, of the component morphemes. Finally, Brent (1994) presented a similar computational treatment of subcategorization frames for verbs. Individual verbs are choosy about what sentence structures they can occur in--for example, some can be transitive (as in *John eats fish*) while others may be only intransitive (as in *John fishes*). Again, based on very little syntactic knowledge (in this case a few function words), an analysis of verbs' lexical contexts provides useful information for distinguishing among verbs that are transitive or intransitive, or that take verbal or sentential complements (as in *John likes to fish*).

Many fundamental questions remain about the role of distributional analysis in syntax acquisition. However, the preponderance of recent evidence suggests that human learners – including and maybe especially the very young--are intricately attuned to the details of their experience, and in many domains show great facility in sorting out and trading off multiple probabilistic indicators of the same underlying structure in the world (see Kelly & Martin, 1994). The view that substantial aspects of language acquisition, from phonology to syntax and semantics, might submit to similar kinds of explanation has benefited in recent years from the wealth of research on phonological learning in infancy, from advances in computational modeling and analyses of large linguistic corpora, and from the study of the constraints, at many levels of analysis, that influence adult (Garnsey, Perlmutter, Myers, & Lotockey, 1997; Trueswell et al., 1994) and child (Trueswell, Sekerina, Hill, & Logrip, 1999; Hurewitz, Brown-Schmidt, Thorpe, Gleitman, & Trueswell, 2000) language processing.

III. The Meanings

Accounts of word and syntax learning are usually accounts of *mapping*. They concern the ways that conceptual entities (concepts of objects, properties, and relations) match up with linguistic entities (words, syntactic categories, and structures). Insofar as this task analysis is correct, it suggests an initial procedure for language learning. Although "meanings" aren't the sorts of object that one can directly observe, aspects of the observed world are often assumed to transparently offer up meanings, and therefore to set language learning into motion. In John Locke's (1690) famous description,

> 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'. (Book 3, IX, 9)

Locke's stance seems warranted. Even at 9 months of age, uttering a word helps to direct an infants' attention to objects in a way that emphasizes to them similarity among category members (Balaban & Waxman, 1997). Children only a few months older apparently begin to map more complicated relational aspects of sentences (e.g., some infant approximation of the category *subject*) onto more abstract relational concepts (e.g., some infant approximation of the category *causal agent;* Hirsh-Pasek and Golinkoff, 1996).

Where do these "meanings" come from? It wouldn't help the learning infant to show it a dog (and say "dog") if this infant couldn't, by its native abilities to observe the world, tell dogs from shoes or ships or sealing wax. We approach these issues by discussing some particularly relevant aspects of the literature on infant cognition (see Gelman and Lucariello, this volume, for extensive review). In this section we briefly defend the claim that pre-linguistic infants' primitive categories of experience include rudimentary concepts of objects and events, sufficiently robust and accessible for them to begin to make sense of linguistic reference.

A. Primitive Categories of Experience

1. The Shape of Things …:Whole Objects and Object Kinds

Before the first word is acquired, infants have acquired a good deal of knowledge about the kinds of objects that exist in their world. The notion *object* itself seems to be based on a primitive set of notions about physical cohesion and a core set of learning mechanisms dedicated to representing and learning about objects. Infants first find coherent objects in the world by assuming that visible surfaces moving together against a variable background are parts of the same thing (Kellman & Spelke, 1983; Jusczyk, Johnson, Spelke, & Kennedy, 1999). The assumptions that objects are solid and exist continuously in space and time are fundamental in this domain, applying generally across different types of events and objects (e.g., Spelke, Breinlinger, Macomber & Jacobson, 1992). Even 2.5-month-olds detect violations of object solidity or continuity, as long as the events are simple enough that they can represent all the required information (e.g., Aguiar & Baillargeon, 1999).

Like adults, young infants come to use disparities in shape as a cue to the boundaries of objects, and also rely on knowledge of particular familiar objects and categories of familiar objects to segment objects out of a complex environment (Needham & Baillargeon, 2000). Pre-linguistic infants do not possess the same rich concepts of objects that an adult has—a 7.5-month-old may think of keys as something delightful to jingle and chew on, the 14-month-old has figured out that they have something to do with big artifacts like cars (Mandler, 2000), while the adult (in most modern environments) attains an enlightened view of keys that specifies their relationship to locks. Despite all the knowledge that we know must be gained by specific experience with the ambient world of things, the infant literature suggests the early appearance of something like kind categories. Infants' object concepts depend on physical similarity (Hume, 1739; Quinn & Eimas, 1997; Mandler, 2000; Smith, Jones, & Landau, 1992), but also support inductive inferences about currently invisible properties of the objects (Baldwin, Markman, & Melartin, 1993; Needham & Baillargeon, 2000). The pre-linguistic appearance of object-kind concepts takes at least part of the mystery out of a topic we shall discuss presently (Section IV), that when infants at the ages of 10 to 15 months begin to understand and utter words, these first vocabularies include a heavy dose of *concrete nouns*.

2. … To Come: … Categories of Events

Some of the best evidence for knowledge-rich categories in early infancy comes from the study of event categories (see Baillargeon, 1998, for a review). Beginning with core representational constraints including object continuity and solidity, infants articulate categories of physical events—such as support, occlusion, containment, and collision—and gradually add knowledge within each category. To account for infants' early expectations about collision events, for example, a primitive notion of force has been proposed as part of the infant's built-in representational vocabulary (Leslie, 1995). Equipped with an ability to attend to and represent solid moving objects, and this notion of force, infants expect objects to move when struck by other objects (Kotovsky & Baillargeon, 1998; Leslie & Keeble, 1987). They gradually elaborate their concept of collision events by adding knowledge about the role of the relative sizes of the striking object and the object it strikes (Kotovsky & Baillargeon, 1998). These infant concepts of physical events really are categories in the usual sense: they are readily applied to new instances of the event type and can support inferences about event outcomes (Baillargeon, 1998). Evidently, then, event categories serve as tractable domains within which infants work out the intricate consequences of physical causality. These event categories interact complexly with abstract object kind categories. For example, as they elaborate their developing concept of collision events, infants learn that not all objects move when hit. Some things are movable objects, while others are fixed barriers that stop the motion of objects that strike them. At 8 months, infants seem to base this categorization on a fairly strict geometric criterion: Anything with a salient vertical dimension is a barrier, anything else is an object (Baillargeon, 1998).

These event categories imply a very useful kind of conceptual structure. Each event category is defined over some set of participants that play different roles in the event, and the participants must be of the correct abstract type to play those roles (e.g., moving object and movable object for collision, container and movable object for containment). Infants' developing event categories provide exactly the sort of relational concepts that will eventually be mapped onto relational terms in their language. The infant's conceptual repertoire appears to entail an early (possibly unlearned) distinction between the *relations* between objects that define event type, and the *objects* or conceptual entities that participate in those events—about "in-ness" apart from particular containers and "hitting" apart from the particular objects involved. This amounts to a distinction between conceptual predicates and arguments, of just the type needed to describe the semantics of sentences (Bierwisch & Schreuder, 1992; L. Bloom, 1970; Braine, 1992; Fodor, 1975).

One strong suggestion that pre-linguistic infants factor their experience into relations and participant roles comes from Alan Leslie's work on the perception of causality. Six-month-olds appear to have an appropriately asymmetrical view of causality: After habituating to a simple computer-generated event in which one shape strikes and launches another, infants found a reversed version of the same event more interesting (Leslie & Keeble, 1987). The infants did not show the same recovery of interest to a reversed event if they had been habituated to an event in which there had been either a spatial or temporal gap between the striking and launched objects. Such gaps interfere with adults' perception of causality in similar events (Michotte, 1963; Scholl & Tremoulet, 2000). Leslie and Keeble concluded that the infants detected the change in mechanical-causal role in the reversed film, in exactly the circumstances where adults would readily perceive the display as causal. The difference between the launching events when played normally or in reverse is in the assignment of participant roles to particular objects: when the film is played backwards, the hitter becomes the hittee.

3. Animacy, Agency, and Intention

The event types just discussed concern relationships among things *qua* physical objects, and mechanical causality. Recent work also suggests that pre-linguistic infants develop the right kind of conceptual vocabulary to be mapped onto talk about intentions. Seminal studies concerning infants' understanding of reaching come from Woodward (1998). She showed 6- and 9-month-olds a simple event in which a hand reached for and grasped one of two toys visible on a stage. After the infants habituated to the repeated presentation of the hand reaching for the bear (not the ball), Woodward presented a test in which, on alternate trials, the hand now reached for and grasped either the same toy in a new location or the other toy in the old location. These events pitted two aspects of event similarity against each other, by changing either the goal object (bear vs. ball) or the goal location and trajectory of reach. Both 6- and 9-month-olds looked longer at the reach to the new goal object, suggesting that they found a reach for a different object more novel than a reach to a different location. When watching a hand reach for an object, young infants apparently focussed on the object reached for; infants did not show the same preference when the "reach" was enacted by an inanimate object. These and other findings testify to the power of a notion of intentional agency in interpreting events. Just as adults are prone to perceive intentionality when watching the apparently contingent, "social" motions of flat geometric shapes (Heider & Simmel, 1944), quite young infants appear ready to interpret interactions in the same way. Intentional agents have goals, they perceive objects and events at a distance, and react to them; self-moving objects can initiate actions, and apply or resist forces (Csibra, Gergely, Bíró, Koós, & Brockbank, 1999; Leslie, 1995; Luo, 2000).

Relatedly, infants between about 9 and 12 months of age show signs of an understanding of the intent to refer: They can follow a pointing finger to its destination, and follow others' line of gaze (Baldwin & Moses, 1996, for a review). These non-verbal indicators of attention play a role in early word-learning. Young children are better able to learn new object-names if an adult names whatever the child is attending to, then when the adult tries to shift the child's attention to another object (Tomasello & Farrar, 1986). Even very young learners need not be fooled into word-mapping errors by these officiously directive acts of labeling, however. A nascent understanding of the intent to refer is engaged in children's early word interpretations: Toddlers glance up as if to check the speaker's intent when they hear a new word produced, and seek the speaker's referent (Baldwin, 1991). Baldwin (1993) found that 19-month-olds attached a new word to whatever the experimenter looked at when she spoke – even if the named object was hidden at the time of labeling, and another object (the wrong object) was made available first. Similar evidence of early sophistication in the interpretation of others' goals emerges from studies of imitation in toddlers: 18-month-olds watched an actor try and fail to (for example) drop an object into a cup, or insert a peg into a hole, and then inferred and imitated the apparent goal of the failed attempts, rather than the actions they observed (Meltzoff, 1995; see also Carpenter, Akhtar, & Tomasello, 1998).

B. Compositional Meaning

Prelinguistic infants and very young word learners develop implicit notions of objects and events, agents and patients, intentions and goals. These conceptual primitives have the right properties to provide the initial conceptual vocabulary onto which the basic linguistic elements (words and structures) are mapped. Language systematically pulls apart unitary states of affairs in the world into separate pieces: It assigns a word to each entity (*kangaroo, gnu*), another for whether that entity is uniquely identifiable in context (*the, a)*, and yet another for the relation holding between the entities (*kicked, tickled*). These words are composed into a sentence, say, *The kangaroo kicked a gnu*. The meaning of a sentence is greater than the sum of its parts, for aspects of the semantics are contributed by their arrangement: *A gnu kicked the kangaroo* means something quite different from the original sequence despite consisting of all and only the same words. A simple sentence (borrowing a metaphor from Healy & Miller, 1970) can be seen as a kind of mystery story whose plot (or *predication*) is the verb, *kick* in this case. The nouns ranged around the verb play varying roles with respect to the predication: The *kangaroo* is the agent or do-er; the *gnu* is the done-to or patient. These nouns are thus the *arguments* of the predicate.

Language partitions and structures the descriptions of entities and events in its basic sentences. We have argued that infants, before language learning, also naturally factor their representations of events into conceptual predicates and arguments. This suggests that prelinguistic human cognition provides conceptual structure of the right type to be mapped onto linguistic expressions. In our view, the best evidence that the structure of human cognition yields a language-appropriate division into predicates and arguments comes from learners who are isolated from ordinary exposure to a language and so have to invent one on their own. No child has to be taught by specific language experience to abstract conceptual predicates away from the arguments that they relate.

The clearest cases of language invention involve deaf children, whose acquisition of a conventional signed language takes place under widely varying input conditions and at different learner ages. The great majority of deaf children are born to hearing parents who do not sign, and therefore the children do not come into contact with gestural languages for years, sometimes for half a lifetime or more (Newport, 1990). Deaf children with no available language model spontaneously invent gesture systems called “home sign” (Feldman, Goldin-Meadow, & Gleitman, 1978; Goldin-Meadow & Mylander, 1984, 1998; Goldin-Meadow, 1982; 2000). Remarkably, though these children are isolated from exposure to any conventional language, their home sign systems factor their experience into the same pieces that characterize the elements of sentences in Latin, Punjabi, and English. Home sign systems have nouns and verbs, distinguishable from each other by their positions in the children’s gesture sequences and by their distinctive iconic properties. Sequences of these gestures vary in the number and positioning of the nouns as a function of what their verbs mean (Feldman et al., 1978). Before unpacking this idea, we want to introduce a new data source that spectacularly rounds out the picture of language learning without a model: This case is the emergence of Nicaraguan Sign Language (NSL).

In the late 1970s, the Sandinista government of Nicaragua opened a school for the deaf , thus bringing together a group of heretofore isolated deaf children of hearing parents. The school advocated an "oralist" (non-signing) approach to deaf education, but the deaf children immediately began gesturing to each other in the playgrounds of the school, using their spontaneously developed and varying home sign systems. This signing, and its evolution at the hands of continuously arriving new deaf students, has been intensively studied ever since (Kegl, Senghas, & Coppola, 1999; Senghas, 1995; Senghas & Coppola, in press; Senghas, Coppola, Newport, & Supalla, 1997). The results of that work, taken at their broadest suggest that, while Rome surely wasn't built in a day, Latin might have been: Born in the mimetic gesturing of linguistically isolated children, NSL exhibits both fundamental organization and certain specialized elaborative choices familiar from the received languages of the world.

The systems that first emerge in home sign systems and in early stages of NSL represent the logic of predicate-argument structure, mapped onto an utterance unit that we might as well call "the basic sentence." This unit can be established both in terms of its universal prosodic correlates, and by its interpretation in context. Each clause typically contains an action or state word with iconic properties so transparent as to convince even the most skeptical observer (e.g., swooping motions of the arm and hand to represent flying, downward fluttering fingers to represent snowing). Now matters really get interesting: Ranged around the verb are other, also recognizable linguistic entities (call them "the nouns") playing the thematic roles required by the logic of the verb – the *agent* or initiator of the act, the *patient* or thing affected, the *goal* of the action, and so forth. "Grape-give-me" signs a 3-year-old home signer; "Man – cry," "Man-tap-cup," gesture the NSL users. Not only are there nouns and verbs, detectable both phonetically and positionally, organized into sentence-like sequences, but *the number of noun-phrases in these sentences is a systematic function of the logic of the particular verb*.

The nature of this relationship is easy to see from the examples just given: Because 'crying' involves only a single participant (the crier), a verb with this meaning surfaces intransitively not only in English and Bengali and Navaho, but also in the speech of young language learners--both those who hear or see a received language and those who perforce must invent it for themselves. Because 'tapping' has two participants, the tapper and the thing tapped, such verbs surface transitively (with two nominal phrases). Because 'giving' requires a giver, a getter, and a thing exchanged between them, this verb shows up with three nominal phrases. The semantic functions of the nouns vis a vis the verb are known as their *thematic* (or *semantic*) *roles* (Chomsky, 1981). Thus the primitive structure of the clause in both self-generated and more established communication systems derives from the nonlinguistic conceptual structures by which humans represent events. This "cognitivist" interpretation of the origin of language in child conceptual structure motivates all modern linguistic treatments of verb semantics that we know of (for important statements, Chomsky, 1981; Dowty, 1991; Fillmore, 1968; Goldberg, 1995; Grimshaw, 1990; Gruber, 1967; Jackendoff, 1983; 1985; Rappaport Hovav & Levin, 1988). The same cognitivist approach figures in most psychological theories about learning of both structure and lexicon, whatever their other disagreements (L. Bloom, 1970; Bowerman, 1990; Braine, 1992; Fisher, 1996; Fisher, Hall, Rakowitz, & Gleitman, 1994; Gentner, 1982; Gleitman, Gleitman, et al., 1988; Pinker, 1984; 1989; Schlesinger, 1988; Slobin, 1996; Tomasello, 2000).

So far we have emphasized the one-to-one relation between the number of participants implied by a verb's meaning and the number of noun-phrases associated with it. One further feature discernable in these invented manual languages, and in toddlers' use of a received language as well, is *a formal means for distinguishing among the participants in the act* – for instance, between the agent and thing affected in a causal act (Goldin-Meadow & Mylander, 1998; Senghas et al., 1997). Established languages employ some combination of local markings on nouns (morphology) and word order to achieve these distinctions, usually emphasizing one of these machineries over the other. For instance, modern English and Chinese are inflectionally impoverished languages that rely on word order, lexical choice, and pragmatics to achieve distinctions that are morphologically rendered (case marked**)** in many other languages such as Latin and Finnish.

Nothing being as simple as it seems, we should mention provisos and complications here. The first is that the very youngest child learners (roughly, between 12 and 24 months) whether learning or inventing a language at first produce only single words, usually followed by a period of several more months where they seem to be limited to two words in the clause. During these earliest periods the full complement of participant roles cannot surface in any single sentence in the child's speech or signing (but even for these early productions the regular mapping between thematic roles and noun-phrase number can sometimes be reconstructed inferentially; L. Bloom, 1970; see also Feldman et al., 1978). Second, even novice speech often allows or requires omission of the *agent* role in certain environments, as in the deaf isolate's imperative "Grape-give-me!" (and its English equivalent), and in many of the world's languages whenever the pragmatics of the situation permit (e.g., Spanish "Hablo Espanol" rather than "Yo hablo Espanol," Goldin-Meadow & Mylander, 1998).

In sum, linguistically isolated children construct, out of their own thoughts and communicative needs, systems that resemble the languages of the world in at least the following regards: All such systems have words, and words of more than one kind, at minimum the nouns and the verbs organized into sentences expressing predicate-argument relations. The number and positioning of the nouns express their semantic roles relative to the verb. Both "nativist" and "learning-functionalist" wings of the language-learning investigative community have seized upon the transparency and universality of form-to-meaning correspondence in language acquisition as supporting their learning positions in particular. (After the battle, the opposing generals retreated to their tents to celebrate their victory).

C. <u>Interactions Between Linguistic and Conceptual Categories</u>

We have just discussed certain primitive conceptual categories that constitute a humanly universal grounding for language acquisition. This is in keeping with a *linguistic universalist* approach maintained by many linguists and developmental psycholinguists who have their attention fixed squarely on the difficulty of explaining language learning (Chomsky, 1965; 1995; R. Clark, 1992; Dresher, 1999; Pinker, 1987; Wexler & Culicover, 1980). These commentators have usually pinned their hopes on their certainty that a well-articulated conceptual structure predates language and is (one of) its required causal engines: "to study semantics of natural language *is* to study cognitive psychology" (Jackendoff, 1983, pp. 3); "…if … couldn't pick pieces of meaning out of the world in advance, before you learned a language, then language couldn't be learnt" (Chomsky, 1982). But now suppose instead that the driving investigative question had been how to "explain concept acquisition" or how to "explain culture" rather than how to "explain language acquisition." When explanatory aims are reversed, so, often, are the certainties about original causes. Psychologists whose problem is to explain the growth of concepts and anthropologists whose problem is explain culture often turn to language itself as a grounding explanatory idea. The intellectual collision of these two traditions has generated a stimulating, but sometimes uneasy, revival of the *linguistic relativity* tradition that had lain submerged for most of the second half of the twentieth century. Perhaps language explains cognition in some way, instead of or in addition to cognition explaining language.

The recent literature points again and again to pervasive behavioral correlates of speaking a particular language. But the basis for such correlational findings is much in doubt and hotly debated. It could be that different peoples speak somewhat differently because as a practical matter – that is, despite their shared mentality – their life circumstances and cultural practices lead them to think somewhat differently and so to choose differently among the available conceptual and linguistic resources. (It could be, for example, that Eskimos talk in such refined ways about snow because they live under conditions where snow and snow types are a big factor in everyday existence). Or perhaps peoples think somewhat differently because they talk somewhat differently. (It could be, that is, that having so many words for snow is what enables the Eskimos to think so precisely about their snowy circumstances – which would be a lucky coincidence for the Eskimos). This idea at its strongest (including the Eskimo example) is the Whorf-Sapir Hypothesis concerning the linguistic shaping of thought[2] (Whorf, 1956).

In Whorf's words,

> the categories and types that we isolate from the world of phenomena we do not find there because they stare every observer in the face; on the contrary, the world is presented as a kaleidoscopic flux of impressions which has to be organized by our minds – and this means largely by the linguistic systems in our minds (1956, p. 213).

And relatedly, from Sapir,

> Human beings do not live in the objective world alone, ... but are very much at the mercy of the particular language which has become the medium of expression for their society. ... The fact of the matter is that the 'real world' is to a large extent unconsciously built upon the language habits of the group. (as cited in Whorf, 1941, p. 75)

We now consider several examples from the recent literature of language acquisition that have been taken to bear on the possibility of the linguistic shaping of thought. In every case, languages differ in how they divide up the same semantic space into linguistic expressions. These differences naturally affect how speakers of these languages speak; after cataloging some of these cross-linguistic variations, we will consider whether such differences have deeper effects on the way we perceive the world.

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[2] According to Pullam (1991), citing Martin (1986), Whorf was incorrect in thinking that Inuit or Yupik dialects are rich in snow words — various morphological and translation confusions and unchecked references led to the gross inflation of a snow vocabulary no more extensive than that found in English. Still, the well-known snow case is a handy example of the way that Whorf and his various intellectual descendents have thought about the relations between language and thought.

1. Categorizing Things and Stuff

The problem of reference to *stuff* versus *objects* has attracted considerable attention because it starkly displays the indeterminacy in how language refers to the world (Chomsky, 1957; Quine, 1960). Whenever we indicate some physical object, we necessarily indicate some portion of a substance as well; the reverse is also true. In light of this general problem, investigators have considered how linguistic and situational clues interact in the linguistic discovery of words for stuff and things. Some languages make a grammatical distinction that roughly distinguishes object from substance reference. Count nouns in such languages refer to objects as individuals. These are marked in English with determiners like 'a,' and are subject to counting and pluralization (*forty thieves; two turtle-doves)*. Mass nouns typically refer to substance rather than object kinds; these are marked in English with a different set of determiners (*more porridge*), and need an additional term that specifies quantity to be counted and pluralized (*a tube of toothpaste* rather than *a toothpaste*).

Soja, Carey, and Spelke (1991) asked whether children approach this aspect of language learning already equipped with the ontological distinction between things and substances, or whether they are led to make this distinction through learning count/mass syntax. They taught English-speaking 2-year-olds words in reference to various types of displays: Some were solid objects, and others were non-solid substances arranged in an interesting shape. The children were shown a sample, named with a term presented in a syntactically neutral frame that marked it neither as a count nor as a mass noun (e.g., "This is *my blicket*"). In extending these words to new displays, 2-year-olds honored the distinction between solid object and non-solid substance displays: When the sample was a solid object, they extended the new word to objects of the same shape, and different material. When the sample was a non-solid substance (e.g., hand cream with sparkles), they went for substance rather than shape. Soja et al. took this as evidence of a conceptual distinction between coherent objects and stuff, independent of (prior to) the syntactic distinction made in English.

This interpretation was put to a stronger test by Imai and Gentner (1997) by extending Soja et al.'s task to a new language, Japanese. Japanese does not have the same count-mass distinction found in English. Speaking somewhat metaphorically, we might say that all of this language's nouns start life as mass terms, requiring a special marker to be counted. One might claim, then, that substance is in some sense linguistically basic for Japanese whereas objecthood is basic for English speakers (see Lucy & Gaskins, 2001, for this position for Yucatec Mayan). If children are led to differentiate object and substance reference by the language forms themselves, the resulting abstract semantic distinction should differ for Japanese and English speakers. Imai and Gentner replicated Soja et al.'s original result by demonstrating that both American and Japanese children (even 2-year-olds) extended names for complex nonsense objects on the basis of shape rather than substance; thus the lack of separate grammatical marking did not put the Japanese children at a disadvantage in this regard. But the Japanese children extended names for the mushy hand-cream (e.g.) displays according to their substance, while the American children were at chance for these items. There were also language effects on word-extension for very simple object stimuli (e.g., a kidney-bean-shaped piece of colored wax). While the Japanese at ages 2 and 4 were at chance on these items, the English speakers showed a tendency to extend words for them by shape. These findings strengthen the evidence for the universal pre-linguistic ontology that permits us to think both about objects and about portions of stuff. But another aspect of the results hints at a role for language itself in categorization--at least where categorization is tested through extension of a new name. Reference to objects that do not clearly demand one or the other construal -- that fall near the midline between “obviously an object” and “obviously some stuff”-- tends to be interpreted as a function of the language spoken.

2. Categorizing Motion Events

Talmy (1985) famously described two styles of motion expression characterizing different languages: Some languages, including English, typically use a verb plus a separate path expression to describe motion events. In such languages the verb is often used to express manner of motion (as in *crawl, clamber, swagger, float,* and *slide*), and the path of that motion is expressed in a prepositional phrase (*out of the room, from the front door to the sidewalk)*. In a language like Greek or Spanish (and most other Romance languages), the dominant pattern is to include path information within the verb itself (as in *salir* “exit” and *entrar* "enter"). The manner of motion often goes unmentioned, or appears as an optional adverbial phrase (“*flotando*"). These patterns are not absolute. Spanish has motion verbs that express manner, and English has motion verbs that express path (*enter, exit, cross*). But several studies have shown that children and adults have learned these dominance patterns. Slobin (1996) showed that child and adult Spanish and English speakers vary in this regard in the terms that they typically use to describe the very same picture-book stories. Papafragou, Massey, and Gleitman (2001) showed the same effects for the description of motion scenes by Greek- versus English-speaking children and, much more strongly, for Greek versus English-speaking adults.

3. Categorizing Spatial Relationships (In-ness and Out-ness)

Choi and Bowerman (1991) studied the ways in which common motion verbs in Korean differ from their counterparts in English. First, Korean motion verbs often contain location or geometric information that is more typically specified separately by a spatial preposition in English. For example, to describe a scene in which a cassette tape is placed into its case, English speakers would say “We put the tape *in the case*.” Korean speakers typically use a verb *kkita* to express the *put in* relation for this scene. Second, *kkita* does not have the same extension as English *put in*. Both *put in* and *kkita* describe an act of putting an object in a location; but *put in* is used for all cases of containment (fruit in a bowl, flowers in a vase), while *kkita* is used only in case the outcome is a tight fit between two matching shapes (tape in its case, one Lego piece on another, glove on hand). Quite young learners of these two languages have already worked out the language-specific classification of motion events in their language (Choi & Bowerman, 1991). Indeed Hespos and Spelke (2000) have shown that 5-month-old infants exposed only to English are sensitive to this distinction.

4. Explaining Language-Specific Categorization

As we have just seen, languages differ to some degree in how they package up conceptual categories inside words and sentence structures. Moreover, manifestly the language users have acquired these language-specific patterns and can use them when called upon to do so in experimental settings. What should we make of these findings, *vis a vis* the relationship between language and thought?

Effects of language on language. One kind of interpretation appeals to effects of language on the interpretation and use of language: Slobin (1996, 2001), P. Brown (2001) and Bowerman (1996) have proposed that native speakers not only learn and use the individual lexical items their language offers, but also learn the kinds of meanings typically expressed by a particular grammatical category in their language, and come to expect new members of that category to have similar meanings. Languages differ strikingly in their commonest forms and locutions -- preferred "fashions of speaking," to use Whorf's phrase. These probabilistic patterns could bias the interpretation of new *words*. Such effects come about when subjects are offered language input (usually nonsense words) under conditions where implicitly known form-to-meaning patterns in the language might hint at how the new word is to be interpreted. As one example, consider again the Imai and Gentner effects for objects and substances. When the displays themselves were of nonaccidental-looking hard-edged objects, subjects in both language groups opted for the object interpretation. But when the world was less blatantly informative (e.g., for waxy lima bean shapes), the listeners fell back upon linguistic cues if available. No relevant morphological clues exist in Japanese (object terms and substance terms have no separate special markers, and so Japanese subjects chose at random for these indeterminate stimuli). For the English subjects, the linguistic cue was in some formal sense interpretively neutral: "This is *my* blicket" is a template that accepts both mass and count nouns ("This is my horse/toothpaste"). But here principle and probability part company. Any English speaker equipped with the roughest subjective probability counter should take into account the massive preponderance of count nouns to mass nouns in English and so conclude that a new word "blicket," referring to some indeterminate display, is probably a count noun with shape predictivity.

Such effects of language on language have been shown again and again. Naigles and Terrazas (1998) found that Spanish- and English-speaking adults differed in their preferred interpretations of new (nonsense) motion verbs in manner-biasing (*She's kradding toward the tree* or *Ella esta mecando hacio el árbol*) or path-biasing (*She's kradding the tree* or *Ella esta mecando el árbol*) sentence structures, used to describe videotaped scenes (e.g., of a girl skipping toward a tree). The interpretations were heavily influenced by syntactic structure (see Section IV, "Mapping Forms to Meanings," for further discussion). But judgments also reflected the preponderance of verbs in each language — Spanish speakers gave more path interpretations and English speakers gave more manner interpretations. Similar effects of language-specific lexical practices on presumed word extension have been found for adjectives (Waxman, Senghas & Beneviste, 1997).

This notion that children develop language-specific expectations for how to interpret words of different grammatical categories can be reached via another inferential route as well. The grammatical categories themselves are not the same across languages. For example, not all languages have distinct categories of prepositions that convey spatial meanings, or of adjectives that name (roughly) stable attributes. Instead, they may use items more like main verbs to convey these meanings (e.g., Croft, 1990; Maratsos, 1990, 1998). If languages have different sets of grammatical categories, then they must have different mappings from grammatical categories to semantic ones. If there is no preposition category, then verbs or perhaps nouns must have more spatial information packaged into them; if there is no adjective category, then property meanings will end up being encoded in words grammatically more like verbs or nouns as well. This, in turn, predicts that when speakers of these various languages are taught a new word, and asked to infer its meaning based on its grammatical category, they will have (for some categories) slightly different views of the options. There are differences in the language patterns, and the speakers use them as a probabilistic basis for inferring how new words will relate to new objects and events.

Does it matter? Linguistic and nonlinguistic classifications. Another question is the extent to which acquisition of these language patterns influences the structure of our concepts, and hence our nonlinguistic categorization, as Whorf and Sapir would have it. The answer to this further question is not so obvious. For example, Hespos and Spelke's demonstration of American 5-month-old infants' sensitivity to the "tight fit" loose fit" distinction vitiates the claim that this distinction "arose from language." The fact that English speakers learn and readily use verbs like *jam*, *pack*, and *wedge* weakens any claim that the lack of commonest terms like *kkita/nohta* seriously diminishes the availability of categorization in terms of tightness of fit. Despite these provisos, some psychologists have speculated, with Whorf, that these speech fashions in turn influence the salience of differing categorizations of the world (see, for example, Bowerman & Levinson, 2001).

Rather different results concerning the influence (or noninfluence) of learned linguistic categories on nonlinguistic cognition come from studies which explicitly compare performance when subjects from each language group are instructed to classify objects or pictures by *name*, versus when they are instructed to classify the same objects by *similarity*. In one such study, Li, Gleitman, Landau, and Gleitman (1997) showed Korean and English-speaking subjects pictures of events such as putting a suitcase on a table (an example of *on* in English, and of *nohta,* "loose fit," in Korean). For half the subjects from each language group, these training stimuli were labeled by the experimenter ("See? Miss Picky likes to put things *on* things"), and for the other subjects the stimuli were described more vaguely ("See? Miss Picky likes to do things *like this*"). Later categorization followed language in the labeling condition: English speakers identified new pictures showing tight fits (e.g., a cap put on a pen) as well as the original loose-fitting ones as belonging to the category "that Miss Picky likes," but Korean speakers generalized only to new instances of loose fits. These language-driven differences disappeared in the similarity sorting condition, in which the word (*on* or *nohta*) was not invoked; in this case the categorization choices of the two language groups were the same.

Another example was reported by Malt, Sloman, Gennari, Shi, and Wang (1999). They examined the vocabulary used by their subjects to label the various containers we bring home from the grocery store full of milk, juice, ice cream, bleach, or medicine (e.g., *jugs, bottles, cartons, juice boxes*). English, Spanish, and Chinese differ in the set of terms available for this domain, and in how these terms are extended to group diverse containers as "the same kind." Speakers of these languages therefore differed strikingly in which objects they classified together by name: For example, a set of objects distributed across the sets of *jugs*, *containers*, and *jars* by English speakers were unified by the single label *frasco* by Spanish speakers. Yet Malt et al.'s subjects did not differ much (if at all) from each other in their classification of these containers by overall similarity rather than by name.

Let us return to the path-manner distinction. Papafragou, Massey, and Gleitman (2001) showed English and Greek speakers series of pictures of motion events, and asked them to (a) describe these events (i.e., to label them linguistically), and either (b) to remember which pictures they had already seen, or (c) to choose a new event "most similar" to the original event. One of the choices in the categorization task shared manner of motion but not path with the original, while the other shared path but not manner. Though subjects showed language-specific preferences for manner or path in labeling these events linguistically, they showed no differences in similarity categorization or memory for path and manner.

Even more surprising is that within-language choice of manner versus path verb neither predicted nor reflected memory or categorization performance *within* language. Papafragou et al. divided their Greek- and English-speaking subjects' verbal descriptions of motion events according to the path/manner distinction, now regardless of native language. Though English speakers usually chose manner verbs, sometimes they produced path verbs; the Greek speakers varied too but with the preponderances reversed. The particular label provided by each subject did not predict classification of the same event. Subjects were not more likely to name events that they had just categorized together as most similar by labeling them with the same verb, and subjects were no more likely, two days later, to correctly reject path changes for an event they had previously labeled with a path (rather than manner) verb, or to more readily detect manner changes for events they had previously labeled with manner verbs.

<u>Sketchiness: Language is no true mirror of our thoughts</u>. These three sets of experiments show an important dissociation between naming on the one hand, and perception and cognition on the other. Naming is a social or conventional act, influenced not only by our perceptions of similarity among objects and events, but also by the somewhat arbitrary details of our linguistic experience. Words are extended, in part by happenstance, to objects or events sharing only partial similarity -- thus in English we use *paper* to refer to a pulped-wood substance, to various objects made of that substance (the daily paper), and to collected ideas expressed on paper (a paper about word extension; see Lakoff, 1987, for many such examples of the vagaries of word extension). Examples like these suggest that we cannot take the details and semi-arbitrary choices of our own words too seriously. As Malt et al. point out, a child may readily call a plastic bear with a straw in its head "a juice box" simply because that's what it's called in the local community. One infant and his parents were perfectly content to use the label "Thank you" to describe all acts of giving and getting. The reason was that this was the only word in the infant's productive vocabulary, yet it served the purpose of making reference to their exchange games perfectly well.

A fair conclusion from this and related evidence is that verbal descriptions are under the control of many factors related to accessibility, including the simple frequency of a word's use, as well as of faithfulness as a description of the scene. Often, given the heavy information-processing demands of rapid conversation, faithfulness is sacrificed to accessibility. For these and other reasons, verbal reports do not come anywhere near exhausting the observers' mental representations of events. Language use is in this sense "sketchy." Rather than "thinking in words" humans seem to make easy linguistic choices which, for competent listeners, serve as rough pointers to those ideas.

In introductory remarks, we pointed out that language users make reference by whatever catch-as-catch-can methods they find handy, leading to some potentially misleading locutions like "Chomsky and Socrates are both on the top shelf" or "The ham sandwich wants his check." What chiefly matters to talkers and listeners is that successful reference be made. If one tried to say all and exactly what one meant, conversation couldn't happen; speakers would be lost in thought as they struggled to get things stated just so, like a population of orators-in-training. Because this is obviously so, listeners would be in quite a pickle if they took their conversational partners' words and structures as precisely indexing the thoughts expressed.

IV. Mapping Forms to Meanings

A. The Mapping Problem

Thus far we have discussed the conceptual underpinnings of language acquisition, arguing that pre-linguistic infants are in possession of usefully-structured concepts that offer up the conceptual vocabulary onto which linguistic elements are mapped. We also reviewed evidence for the infant's impressive abilities in the formal analysis of linguistic elements. During the first year, infants learn an enormous amount about objects and events in the world, and about the distributions of sounds and words in their native language. Apparently, when the infant approaches one year of age – at about the time that word-mapping gets underway – she is capable of representing both linguistic and conceptual entities in ways conducive to language learning. Moreover, we have seen that young children invent their own home-sign systems, and that these systems are fundamentally similar to more established languages.

This may sound like it solves all problems: Toddlers starting to learn language are "creatures like us" in many respects. But richness of representation is a double-edged sword. On the one hand, surely nobody could learn language without the ability to conceive of objects and events in the many and various respects encoded by any language (and all languages). On the other hand, this essential multiplicity and flexibility of cognitive life makes word-mapping seem less tractable. How does the child figure out which of the many ways in which she can think about objects and events is meant by a particular word? Or, given that a toddler can factor a complex event into its participants and the relations among them, how is she to know which word maps onto which element of the scene representation?

Recent evidence suggests that observation of words' extralinguistic contexts, across multiple uses, does provide the kind of information needed to identify some words. The evidence suggests, however, that simple observation of word-world contingencies works better for learning some words than others. Gillette, Gleitman, Gleitman, and Lederer (1999) carried out "human simulations" of observational word learning: They showed adult observers silent video clips of mothers talking to their toddlers, and asked the observers to guess what word the mother said to her child whenever a beep occurred on the tape. The beeps were positioned at just the points at which the mothers had uttered one of the 24 most common nouns, or 24 most common verbs, found in the sample of child-directed speech from which these video clips were drawn. Subjects saw six clips for each word, presented in a row, and were told that each series of six beeps marked utterances of the same word. Thus they had an opportunity for some cross-situational observation to guide the interpretation of each word; in the initial studies they were told whether the words were nouns or verbs; in a replication by Snedeker & Gleitman (in press) the beeps were not identified by lexical class. In both experiments, adults were much better able to guess the mothers' nouns than their verbs.

Success rates in this task could be predicted by other subjects' judgments of the concreteness of each word. On average, the common nouns in the mothers' speech were judged more concrete than the common verbs. Variability in judged concreteness was a better predictor than the noun/verb distinction of which words were successfully inferred from observation of the scenes. The most concrete verbs (e.g., *throw*) were identified relatively frequently, while the most abstract verbs (e.g., *think, know*) were never guessed correctly by any subject. This suggests a fairly simple account of which words will be most efficiently learned based on simple observation of scenes in which they are used – the most concrete words, including a useful vocabulary of concrete nouns, are just those for which linguistically unaided observation is likely to be informative.

The Gillette et al. data suggest that the solution to the mapping problem may not be as simple as suggested by Locke's sanguine expression quoted earlier: "We…show them the thing…". Observation of 'the thing' appears to be sufficient for the acquisition of some but not all of our vocabulary. The trouble with verbs and other predicate terms is that they're abstract – verb meanings depend not only on the event, but also on a choice of perspectives on events (e.g., Bowerman, 1985; Choi & Bowerman, 1991; E. Clark, 1990; Fillmore, 1977; Fisher, 1996, 2000a; Fisher et al., 1994; Gleitman, 1990; Goldberg, 1995; Grimshaw, 1994; Landau & Gleitman, 1985; Pinker, 1989; Rispoli, 1989; Slobin, 2001; Talmy, 1985). This perspective can be surprisingly unpredictable from observations of the events themselves. For example, perspective-changing verbs like *chase* and *flee* describe the same class of events, but differ in their focus on the perspective of one or the other participant in the event. Similarly, one cannot say *give* if nobody *gets*, and every time one *puts* the cup on the table**,** the cup also *goes* on the table**.** Linguistic perspective on an event is influenced by many factors, including the words and structures the language makes available (e.g., Bowerman, 1990; Choi & Bowerman, 1991; Talmy, 1985), and the momentary accessibility of particular words and syntactic structures (e.g., Bock, Loebell, & Morey, 1992).

Responding to Locke's analysis of the mapping problem, Landau and Gleitman (1985) examined word and syntax acquisition in congenitally blind children. From the purest of empiricist perspectives, the consequences of sensory deficits like blindness for relevant conceptualizations should be fatal. Here is Hume on this topic:

> …wherever by any accident the faculties which give rise to any impression are obstructed in their operations, as when one is born blind or deaf, not only the impressions are lost, but also their correspondent ideas; so that there never appear in the mind the least trace of either of them. (1739/1978, p. 49).

Descriptively, the outcome of Landau and Gleitman's investigation was that blind and sighted children were remarkably alike both in the rate and the content of their language learning. Correcting for neurological problems often associated with congenital blindness, the two populations started to talk at about the same time, the semantic content of their early vocabularies was alike, and they proceeded in the same steps toward the acquisition of the structures of the exposure language.

Of particular interest in the present context is the acquisition of words that Locke called "of one sense only," that is, items whose experiential basis would appear to come uniquely from vision. Two cases studied by Landau and Gleitman were vision verbs (*look, see*, etc.) and color terminology (*color, green, red*). Sighted blindfolded 3-year-olds told to "Look up!" turned their faces skyward, suggesting that they interpreted 'look' to implicate vision in particular. A blind 3-year-old given the same command raised her hands skyward instead, suggesting that for her the term was connected to the manual sense. Thus the difference in observational opportunities led the two populations to different interpretations of the same term, just as Locke would have expected: successful communication from mother to blind child using this term often occurred just when the objects to be looked at were in the learner's hands, licensing a physical contact interpretation of blind looking. However, as these investigators also showed, several common verbs used by the mother to the blind child shared the property of being uttered—and proportionally even more often than *look*—, when the child had a relevant object in hand; namely, *hold, give, put* and *play*. Moreover, the blind child's interpretation of *look* went beyond manual contact. When told "You can touch that table but don't look at it!," the blind child gave a gingerly tap or scratch at the table. Then told "Now you can look at it," the child explored the surfaces of the table manually. Based on this kind of evidence, Landau and Gleitman concluded that blind *look* (a) semantically differed from sighted *look* by implicating a different sense modality, but (b) semantically resembled sighted *look,* and differed from *hold, touch*, etc., in being a term of perception. In sum, we can easily account for the blind child's failure to map *look* onto the visual modality, from an orthodox associative perspective on word learning that focuses on the necessity of extralinguistic observation. But this perspective cannot so easily explain how the blind -- and sighted learners -- hit upon looking as a perceptual rather than contact term. Again, these findings suggest that extralinguistic observation is insufficient as a full explanation of word learning.

The blind child's understanding of color terms offers a similar insight: The blind subject of Landau and Gleitman's case study knew that (a) *color* is the supernym for a subset of adjectival terms including *green, red,* but not *clean, happy;* and (b) that these terms apply only to concrete objects. To illustrate, though children (blind or sighted) have no experience of either *blue dogs* or *yellow ideas*, their responses to these two types of property violation were systematically different. Asked "Can a dog be blue?" the blind child at 5 years of age responded with different color terms: "A dog is not even blue. It's gold or brown or something else." Asked "Can an idea be yellow?" the child responded "Really isn't yellow; really talked about – no color but we think about it in our mind." These findings display the remarkable resilience of semantic acquisition over variations of input: Lacking the ordinarily relevant observations that support the learning of visual terms, a blind child nevertheless detected some information in the use of these words that told her *what kinds of concept* they denoted.

How should we explain the robustness of semantic aspects of language learning in the face of the ordinary variability of experience, and the vast array of reasonable semantic alternatives? The hypothesis we will consider here is that vocabulary acquisition can get off the ground because some set of lexical items—mostly concrete nouns— can be learned by observation of the world alone. As Gillette et al. demonstrated, this kind of learning ("word to world pairing") yields a limited concrete vocabulary even for adults. These items provide required scaffolding for the interpretation of more abstract words, including predicate terms (verbs, adjectives, prepositions). This linguistic information helps in a variety of ways, some of which are more helpful for some terms than others. First, known words can narrow the meanings of new ones via some form of lexical contrast. Second, a stock of known words can aid the acquisition of new words of the same grammatical category by giving semantic consequences to the morphological or syntactic cues that pick out new members of that category (R. Brown, 1957) -- we have already alluded to this influence in discussing apparent effects of language on conceptualization of events. Third, the nouns constitute arguments for predicate terms, and so serve as a foundation on which the children build a rudimentary representation of the phrase structure of the input language (Fisher et al., 1994; Fisher, 1996; Gillette et al., 1999; Snedeker & Gleitman, in press).

B. Concrete Words First

Many studies show that children's early production vocabulary is dominated by concrete nouns--names for objects and people, in particular (see Gentner & Boroditsky, 2001, and Woodward & Markman, 1998, for reviews). This is true in languages other than English, even in languages like Italian (Caselli et al., 1995), Mandarin Chinese (Tardif, S. Gelman, & Xu, 1999), Korean (Au, Dapretto, & Song, 1994; cf. Choi & Gopnik, 1995), and Japanese (Fernald & Morikawa, 1993) that possess surface properties conducive to verb learning, including the omission of noun phrases when they can be inferred. Such factors do affect productive verb vocabularies: a checklist study of early vocabularies in Mandarin Chinese revealed a significantly smaller noun advantage for Chinese- than English-speaking children, suggesting that the frequent appearance of isolated verbs in speech to children creates enhanced opportunities for learning verbs (Tardif et al., 1999; but see also Snedeker and Li, 2000, who have data suggesting that the most potent factor may be that Chinese mothers are far less likely than American mothers to use abstract verbs such as *think* and *like* to their toddlers).

A bias toward learning object names is present in the earliest language comprehension as well. As noted earlier in this review, novel words presented in object-manipulation contexts cause 9- to 13-month-olds, as well as older children, to focus on the kinds of similarity across objects that can indicate shared category membership (Markman & Hutchinson, 1984; Balaban & Waxman, 1997; Waxman & Markow, 1995; Woodward & Markman, 1998). When a new word is presented, the object-kind interpretation is often so salient that it's difficult to get children to arrive at any other interpretation (P. Bloom, 2000; Gentner, 1982; Maratsos, 1990).

Other things being equal, children prefer object categories at the relatively concrete "basic" level of categorization (the ordinarily used "bird" level of categorization in the *robin-bird-animal* hierarchy; e.g., Hall & Waxman, 1993). This preference on the part of the child maps neatly onto the naming practices of adults, at least in English parent-child conversations: Parents tend to give things their basic-level names before naming their parts, before invoking a superordinate label, or before using a situation-limited label like *passenger* (e.g., Callanan, 1985; Hall, 1994; Ninio, 1980; Shipley, Kuhn, & Madden, 1983).

The object-naming preference in early word learning is not an absolute bias. Though names for things predominate in early production and comprehension vocabularies, very young children also learn property terms (*hot, dirty*), action words (*walk, kiss*), directional particles (*up, out*), terms for substances (*milk, juice*), and other oddments (*bath, noise*; e.g., Caselli et al., 1995; Nelson, Hampson, & Shaw, 1993). Children as young as 15 months old understand some verbs in sentences (e.g., Hirsh-Pasek & Golinkoff, 1996); children learn and produce verbs during the second year (e.g., Tomasello, 1992).

The Gillette et al. (1999) evidence reviewed above yields a simple explanation for the probabilistic noun dominance of the earliest vocabulary. The adult subjects in Gillette et al.'s studies had already grasped the concepts lexicalized by all the English words to be guessed in the study. Nevertheless, only the most concrete words were successfully identified from observing the extralinguistic contexts alone. Children's first words are determined by the tools available for word learning. The true beginner can only try to observe elements in the world that systematically occur with the use of particular words. This leads to success in those cases in which the word's meaning is concrete enough to be readily observable in the flow of events: mostly nouns, but also a heterogeneous set of other words. To learn less concrete (less observable) terms, the learner needs other kinds of evidence--linguistic evidence, bootstrapped from the previously acquired vocabulary of concrete words.

Another proposal that has much in common with ours is that of Gentner (1982; Gentner & Boroditsky, 2001). Gentner argues that nouns fall toward the concrete, easy-to-grasp end of a conceptual-linguistic continuum along which word categories vary in their appearance across languages. Names for people and objects uniformly surface as nouns across languages, while words for properties, locations, substances, actions, and so forth, vary both in what kinds of information are conflated into the same word, and in their organization into grammatical categories (e.g., Bowerman, 1990; Maratsos, 1998; Talmy, 1985). The less concrete terms thus are more dependant on linguistic learning. The only aspect of this argument as expressed by Gentner and Boroditsky (2001) that we cannot agree with is stated in the first paragraph of their paper: "the world presents perceptual bits whose clumping is not pre-ordained, and language has a say in how the bits get conflated into concepts" (pp. 215). We would amend: "Language has a say in how the conceptual bits get conflated into *words*." As we have already testified at some length, *the semantic organization of the lexicon is surely language-specific, but the meanings of our words do not exhaust our knowledge*.

C. <u>Old Words Make New Words Easier to Learn</u>

The true linguistic novice can pick up a small stock of concrete words, learned via word-to-world mapping unaided by prior linguistic knowledge--but aided by all the conceptual apparatus and nascent understanding of human intentions described in Section III (for discussion, Pinker, 1984). This step boosts the child into a better position to learn other words, and to begin to work out the phrase structure of the exposure language.

1. <u>Mutual Exclusivity, Lexical Contrast, Suppletion</u>

Some notion of a simple contrast between words is widely assumed as an explanatory force in lexical acquisition. The most familiar demonstration was reported by Markman and Wachtel (1988): 3-year-olds were presented with two objects, one familiar (e.g., a cup), and one they could not name (e.g., a wire whisk). Asked to give the experimenter "the blicket," the children handed over the whisk, appearing to assume the new word didn't apply to an already-named object. Children also use their knowledge of familiar words to overcome the preference for object-category interpretations: In another of Markman and Wachtel's experiments, 3-year-olds interpreted a novel word applied to a familiar object as a name for a salient part – for example, the boom on a fire truck. Effects like these have been demonstrated in many different settings, and with different categories of words (e.g., substance terms, property terms, verbs; see

P. Bloom, 2000, and Woodward & Markman, 1998, for reviews). Old words seem to repel new ones, directing inferences toward conceivable interpretations that have not yet been picked out by a word. Once any set of word meanings is known, they provide a new source of bias in word interpretation.

Accounts of how children achieve this useful behavior vary. Markman and Wachtel proposed a Mutual Exclusivity principle, which holds that each object has exactly one name. This is a preference or a bias, not an absolute constraint; thus it permits the acquisition of second names for things based on strong linguistic evidence (Liittschwager & Markman, 1994). Clark (1987) proposed a principle of Contrast, which holds that any two linguistic forms (words, but also syntactic formats) differ in their meanings, and a principle of Conventionality, which holds that there is a preferred, ordinary way of making reference to each thing. This permits the hearer to make the pragmatic inference that if the conventional name wasn't used, something else must have been meant. On either view, old words influence the induction of meanings for new words. Some form of contrast between lexical items, also known as suppletion, plays a role in virtually every theory of word and syntax acquisition. The child's existing knowledge of language (or whatever part of it can be retrieved at the moment) is used to interpret each utterance, by boosting the salience of interpretations for which the child does not already have a word.

2. Differentiating Grammatical Categories

We earlier reviewed evidence that children make progress in the creation of grammatical categories via a distributional analysis over linguistic forms. This analysis, however, proceeds at the same time that children are learning the meanings of words. Distributional analysis gives children an enormously powerful source of information for grouping words into semantic as well as grammatical categories: Even though the grade-school definitions of parts of speech are inadequate in detail, grammatical categories are probabilistically related to abstract semantic categories across languages (L. Bloom, 1998; Grimshaw, 1981; Macnamara, 1982; Maratsos, 1998; Pinker, 1984: Schlesinger, 1988). The abstract semantic coherence of grammatical categories has at least two effects: (a) once a category has been formed, even in part, learners can determine the grammatical categories of new words whose meanings they know; and (b) if the grammatical category of a word can be inferred from its distributional signature, its meaning can be inferred with less error.

The differentiation of grammatical categories begins early. By 13 months of age infants infer a property interpretation of a new word (e.g., 'yellow' things) if the set of objects the infants are shown does not support an object-category interpretation, and if the new word is presented as an adjective, not as a count noun (e.g., "a daxish one", not "a dax"; Waxman, 1999); count nouns are interpreted as object-category names by 12-month-olds (Waxman & Markow, 1995). These infants have apparently already picked up some of the morphological cues that identify count nouns in English, and use them to guide word mapping (see also Waxman & Hall, 1993). By 18 months to 2.5 years, children extend a novel count noun ("a dax") to other, similar objects, but restrict their extension of a novel noun with no determiner to the named individual (a proper name, "Dax"; Katz, Baker, & Macnamara, 1974; S. Gelman & Taylor, 1984; Hall, 1991). Two- and 3-year-olds use count- and mass-noun syntax ("a dax" vs. "some dax" to choose between substance and object interpretations of new words (Soja, 1992). This process culminates in the performance of preschoolers in Roger Brown's famous experiment (1957), who indicated that “a dax” was an object, “some dax” was a non-solid substance, and “daxing” meant an action.

The morphological markers of grammatical class are language-specific and must be learned. This learning depends on the formal analysis required to achieve word and morpheme segmentation, and on the acquisition of a sufficiently large set of words within a category to identify its morphological signature. In addition, as mentioned above, the grammatical categories themselves are not the same across languages (e.g., Croft, 1990; Maratsos, 1998). Children must achieve a language-specific differentiation of predicate types (verbs, prepositions, adjectives). On the current view, this differentiation is based on the distributional, semantic, and phonological similarity of items within grammatical categories. These categories, perforce, have language-specific semantic consequences. Learners of a language that does not have the same split between noun and adjective meanings should not show the same word-interpretive preferences when given new members of these categories (see Waxman et al., 1997).

Inference from language-specific grammatical categories provides a way for early vocabulary learning to guide further word learning. Closed-class cues to grammatical class are not all-powerful, however, for a variety of reasons. First, to the extent that the child's earliest vocabulary consists mostly of elements from one class (nouns), other linguistic evidence will be required to begin to interpret and identify other word types. Second, assignment of a novel word to a specific grammatical category depends on the identification of function morphemes. These short and unstressed items should be relatively hard to detect in connected speech. Though very young children are sensitive to some of the function morphology found in noun and verb phrases (Gerken et al., 1990; Santelmann & Jusczyk, 1998; Waxman, 1999), this surely does not mean they identify these elements without error. Like any linguistic cue, morphological cues to grammatical category will influence interpretation only to the extent that children correctly analyze the given string of morphemes. Third, correct assignment to a grammatical category offers quite abstract evidence about the meaning of a new word. Even the youngest child's nouns are not all object-names (e.g., Caselli et al., 1995; Nelson, 1988). Apparently the child is not forced by morphology to interpret *bath* or *sky* as an object category name just because it is presented as a count noun. Finally, and relatedly, in any instance of mapping a word form (guided by the available syntactic hints) onto some interpretation of the world context, what is available and most salient in the child's conception of the context will also constrain interpretation. For all these reasons, though preschoolers can use closed-class cues to grammatical form class in interpreting new words, they do not always manage to do so. The presence or absence of closed-class markers can persuade children to arrive at property or substance interpretations of a new word (e.g., "This is a zavish one" rather than "This is a zav", or "This is pewter"), but preschoolers are more likely to show sensitivity to such cues if the new word is presented in the context of objects whose basic-level names are already familiar (Hall, Waxman, & Hurwitz, 1993; Markman & Wachtel, 1988) or provided ("a zav horse"; Mintz & Gleitman, 2001).

3. Nouns as Scaffolding for Sentence Interpretation

How does the child move beyond an initial concrete vocabulary (mostly nouns), and begin to learn words of other classes? The indirect relationship between verb meaning and world events makes verb learning in particular somewhat mysterious. The view known as *syntactic* *bootstrapping* proposes that the interpretation of verbs and other predicate terms is guided by information about the structure of the sentence in which the verb appears (Landau & Gleitman, 1985; Gleitman, 1990; Naigles, 1990; Fisher et al., 1994; Fisher, 1996, 2000a; Gleitman & Gleitman, 1997). Most generally, this view proposes that word learning after the first primitive steps proceeds by sentence-to-world pairing rather than merely by word-to-world pairing.

To illustrate, let us return to the Gillette et al. (1999) "human simulations" described above. Gillette et al. repeated their experiment, asking adults to guess verbs spoken to young children based on various combinations of linguistic and extra-linguistic information. Adults were much more accurate in guessing which verb the mother said to her child when given information about the sentence in which the verb occurred. When given a list of the nouns that occurred in the sentence (alphabetized to remove word order information), along with the scene in which the verb was produced, subjects' guesses were significantly more accurate than when given the scene alone. More elaborated syntactic information made subjects' guesses still more accurate: When presented with the complete sentence with the verb replaced by a nonsense word (much as in Carroll's poem, *Jabberwocky*), subjects' guesses were quite accurate even without access to the scenes, and nearly perfect with both sentence and scene.

Why would syntactic information so strongly guide semantic inferences? These effects stem from the same fundamental links between syntax and semantics discussed in the context of the invention of languages. Verbs vary in their syntactic privileges (i.e., the number, type, and positioning of their associated phrases). Quirks and exceptions aside, these variations are systematically related to the semantic argument-taking properties of the verbs (e.g., L. Bloom, 1970; Croft, 1990; Fillmore, 1968; Fisher, Gleitman, & Gleitman, 1991; Gleitman, 1990; Goldberg, 1995; Grimshaw, 1981, 1994; Gruber, 1967; Levin & Rappaport Hovav, 1995; Pinker, 1989). A verb that describes the motion of an object will tend to occur with a noun phrase that specifies the 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 person to another will take three arguments. Similarly sensible patterns appear for argument type: a verb like <u>see</u> can take a noun phrase as its complement (because we can see objects), but also can take a sentence as its complement because we can perceive states of affairs. To the adults in Gillette et al.'s studies, therefore, or to a suitably constructed young learner, sentences can provide information about the semantic structure of the verb in that sentence, providing a kind of "linguistic zoom lens" to help the learner detect the verb's perspective on the event. The evidence from language invention earlier reviewed sharply focuses our understanding of these syntax-semantic correspondences and how they feed the language learning process. Certain of these fundamental correspondences between the argument-taking aspects of predicates and their realizations in syntactic structure need not be learned, but in some skeletal form come for free, as shown in the sentence forms of Goldin-Meadow's isolates and the child inventors of NSL. Landau and Gleitman (1985) conjectured that just such linguistic systematicity accounts for how the blind learner concludes that *see* is a perceptual term.

According to syntactic bootstrapping theory, what goes for these special populations goes for more normally circumstanced learners as well. Learning of words takes place in situations of massive variability and ambiguity. But as for the structures, they too provide only partial evidence as to the meaning of words they contain. Verbs that share a syntactic structure can vary greatly in their semantic content: Transitive verbs include *see, like,* and *break*; intransitive verbs include *sleep* and *dance*. The semantic information that might be inferred from sentence structure could be described as relevant to the sentence's semantic structure -- how many and what participants are involved -- rather than the event-dependent semantic content (sleeping vs. dancing; see Fisher et al., 1991; Grimshaw, 1994). But this abstract information is precisely what is not routinely available in observations of events. Taken together, the data of event observation and linguistic observation converge in an efficient learning procedure for vocabulary and syntax.

4. <u>Children's Use of Syntactic Evidence in Sentence Interpretation</u>

Many studies show that children between about 2 and 5 years old use syntactic cues in sentence interpretation, arriving at different interpretations of verbs presented in different sentence structures (e.g., Fisher, 1996, in press; Fisher et al., 1994; Naigles, 1990; Naigles & Kako, 1993). Naigles (1990) showed 25-month-olds a videotape depicting two concurrent events--in one case, a duck bent a bunny into a bowing posture, while both duck and rabbit made arm circles. Children heard a new verb used to describe this composite scene; half of the children heard a transitive verb, as in (1), and half of the children heard an intransitive verb, as in (2). Following this introduction, the two parts of the composite event were separated onto two video screens. Now one screen showed the causal action of the duck on the bunny (causing-to-bow, but no arm-waving), while the other showed the simultaneous action of the duck and the bunny (arm-waving, but no causing-to-bow). When exhorted to "Find kradding!", the children who had heard the transitive sentence (1) looked longer at the causal scene, while those who had heard the intransitive sentence (2) looked longer at the simultaneous action scene. These 2-year-olds used syntactic evidence to infer which event in a complex scene was described by a new verb.

(1) The duck is kradding the bunny!

(2) The duck and the bunny are kradding!

Similar syntactic evidence can persuade young children to alter their interpretation of a familiar verb. Naigles, Gleitman, and Gleitman (1993) asked preschoolers to act out sentences using a toy Noah's Ark and its associated characters. The informative trials were those in which a verb was offered in a new syntactic environment, as in "Noah brings to the ark" or "Noah goes the elephant to the ark." Young children adjusted the interpretation of the verb to fit its new syntactic frame, for example acting out *go* as "cause to go" when it was presented as a transitive verb. Sentence evidence can also cause preschoolers to focus on different aspects of the same event in interpreting a novel verb (Fisher et al., 1994).

The sentences in these studies provided many language-specific sources of evidence: the set of familiar nouns in the sentence, their order relative to each other and relative to the new verb, and English functional elements like <u>and</u> and <u>to</u> that specified how particular noun phrases were to be linked into the sentence structure. A recent series of studies was designed to isolate particular features of a sentence's structure, asking what aspects of the structure young children find meaningful. In several studies, 2.5, 3-, and 5-year-olds (Fisher, 1996; in press) heard novel verbs used to describe unfamiliar causal events; the verbs were presented either transitively or intransitively. The sentences contained only ambiguous pronouns, as in (3); thus the sentences differed only in their number of noun phrases. The children's interpretations of the novel verbs were tested by asking them to point out, in a still picture of the event, which character's role the verb described ("Who's pilking (her) over there?"). Both adults and children at all three ages were more likely to select the causal agent in the event as the subject of a transitive than an intransitive verb. Just as for the adult judges in the Gillette et al. studies, these findings provide evidence that the *set of noun phrases* in the sentence--even without information about which is the subject--influences young children's interpretations of verbs. Even 2.5-year-olds interpret the subject's role differently depending on the overall structure of the sentence.

(3) She's pilking her over there.

She's pilking over there.

Compare these results with the innovations of the deaf 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. Elsewhere we have proposed (Fisher et al., 1994; Fisher, 1996, 2000a; Gillette et al., 1999) that children might arrive at this structure-sensitive interpretation of a sentence in a simple way -- by aligning a representation of a sentence with a structured conceptual representation of a relevant situation. In this way a child might infer that a sentence with two noun arguments must mean something about a conceptual relationship between the referents of the two nouns, while a sentence with only one noun argument might describe a state, property, or act of the single participant. This simple structure-mapping could take place as soon as the child can identify some nouns and represent them as parts of a larger utterance. The familiar nouns in the sentence might provide a partial or skeletal sentence structure that would constrain interpretation.

Arguments and adjuncts. Immediate objections to this "counting the nouns" procedure might come to mind. First, *nouns in the sentence* are not the same thing as *arguments of the verb*. In many languages, sentence subjects can be freely omitted if they are recoverable from context and prior discourse; in some languages, including Chinese, Japanese and Korean, verb's direct objects can be omitted as well (e.g., Clancy, 1985; Rispoli, 1989). These well-known facts guarantee that many individual sentences in casual speech will not display the complete set of the verb's arguments. In addition, sentences can contain more noun phrases than argument positions. The distinction between arguments of a verb and adjunct phrases (“with Ginger”, “in the morning”) that can be added to almost any sentence is a notoriously slippery one, difficult to define across languages (e.g., Croft, 1990).

Despite the somewhat messy relationship between nouns in sentences and the syntactically subcategorized arguments of the verb, several sources of evidence suggest that ordinary sentences provide strong probabilistic information about the participant structures of verbs. Brent's (1994) simulations of verb subcategorization frame learning from spontaneous child-directed speech, described in Section II above, testified to the robustness of information about verb subcategorization in input sentences. Lederer, Gleitman, and Gleitman (1995) showed that the syntactic contexts of verbs in speech to young children powerfully predicted judged verb-semantic similarity. In the "human simulations" of Gillette et al. (1999), adults benefited from simply being given an alphabetized list of the nouns in each sentence in which the mothers had produced a particular verb. In this case the adults (like the hypothetical learner) could not tell which nouns were arguments of a verb and which were adjuncts, yet this linguistic hint aided recovery of verb meanings from scenes. Li (1994) analyzed speech to young children in Mandarin Chinese, and found that although mothers did omit noun phrases in sentences, maternal utterances still supported a strong differentiation among semantically and syntactically distinct classes of verbs. Though arguments can be omitted, transitive verbs still occur with two nouns in the sentence more often than intransitive verbs do. Considerable evidence tells us that young children are quite good at learning about the sentence structures in which particular verbs occur (e.g., Gordon & Chafetz, 1990; Tomasello, 2000); such findings suggest that young children may well be capable of taking advantage of probabilistic evidence, presented across multiple sentences, for the range of sentence structures assigned to each verb.

<u>Learned correspondences between syntax and meaning</u>. A second objection is essentially the reverse of the first: The findings reported so far are consistent with the view that there is a bias to map one-to-one between the set of arguments of the verb and the set of participants in the event, in children acquiring an established language as well as for linguistic isolates inventing their own sign systems. But perhaps, in the case of children learning an established language, the early honoring of this simple mapping from participant number to noun-phrase number is an effect of language learning rather than the reflection of some unlearned bias. Language-specific aspects of the mapping between syntax and meaning affect sentence interpretation from an early age: Hirsh-Pasek and Golinkoff (1996) showed English-learning 17- to 19-month-olds two videos displaying the same familiar action, differing only in which participants were the do-er and done-to in each. The infants' attention to the two screens revealed sensitivity to word order (e.g., "Cookie Monster is tickling Big Bird" vs. "Big Bird is tickling Cookie Monster"): They looked longer at the screen on which the subject of the test sentence was the agent of the action. Children 26 and 21 months old show the same sensitivity to English word order when presented with made-up verbs and unfamiliar actions (Fisher, 2000b). Very young children acquiring a free word-order language acquire the semantic implications of case-marking morphology by age two (e.g., results for Turkish learners reported in Slobin, 1982). Do children simply exploit the most stable cues to mapping made available in the language they hear, rather than relying on an unlearned bias for one-to-one mapping?

To investigate this issue, Lidz, Gleitman, and Gleitman (2000) asked preschoolers to act out novel combinations of verbs and syntactic structures in two languages: English (as in Naigles et al., 1993) and Kannada, a language spoken in Eastern India. Kannada permits pervasive argument dropping, rendering the relationship between argument number and noun-phrase number relatively variable in typical input sentences. Kannada also has, however, a causative morpheme that only occurs with causative verbs. The critical sentences pitted argument number (two nouns vs. one) against causative morphology (explicitly marked as causal or not). Kannada-speaking 3-year-olds ignored the presence or absence of the causative morpheme, relying only on the number of noun-phrases in the sentence they heard. In contrast, Kannada-speaking adults' enactments were influenced by both morphology and argument number. The adult findings again demonstrate that language learners ultimately acquire whatever cues to sentence meaning the exposure language makes available. But strikingly, they also show that children are not totally open-minded – they appear to find some formal devices (argument number) more potent than others (inflectional morphology).

Summary: Consequences of one-to-one mapping. Given the inevitable mismatches between number of nouns in a sentence and number of arguments of a verb, the structural alignment procedure yields a number of interesting consequences for learning, predicting both useful properties and errors which the learner will need to overcome (see Fisher, 2000a). One advantage of structural alignment is that it could guide the interpretation of any argument-taking predicate term. A one-to-one mapping of nouns in sentences onto participants in conceptual representations of scenes provides no basis for distinguishing between different classes of argument-taking words like verbs, adjectives, and prepositions. This lack of specificity could be useful, given the cross-linguistic variability in categories of predicate terms (e.g., Croft, 1990). Maratsos (1990; see also Braine, 1992) has suggested that children might approach language acquisition expecting a basic syntactic distinction between referential and relational words, analogous to the semantic distinction between arguments and predicates.

The notion that children can interpret sentence structure as a general analog of predicate-argument semantics could help to explain how the child figures out which words are argument-taking predicates in the first place: Landau and Stecker (1990) taught 3-year-olds a novel word that the experimenter introduced as she placed an unfamiliar object on top of a box. The word was presented either as a noun ("This is a corp") or as a preposition ("This is acorp my box"). Children who heard the word presented as a noun considered that an object in any location relative to the box could be "a corp," but resisted changes in the object's shape. Children who heard the word presented as a preposition accepted shape changes but maintained that only objects in certain locations could be "acorp the box." Having arguments, "is acorp" was taken to refer to a relation between the referents of those arguments.

V. Where Learning Ends

We have tried in this review to bring together some of what is currently known about the spectacular and species-uniform programmed learning capacity for language. We have reviewed evidence for the infant's remarkable capacity for learning about the idiosyncrasies of particular languages, but also for powerful constraints that structure the mapping of ideas onto linguistic expressions. One matter we have left aside until now is that this capacity does not persist forever and unchanged in species members. Sufficient witness are the heavy accents and fractured grammars characteristic of many brilliant, but foreign-born adults – be they architects, physicists, philosophers, and even linguists. Adults who may solve quadratic equations cannot equal the achievements of the most ordinary native-born 5-year-old in mastering the relative clause and verbal auxiliary.

Much of our knowledge on this topic has traditionally come from studies of second language learning, for the obvious reason that it is hard to find adults who have not been exposed to a language early in life. In general, the findings are these. In the first stages of learning a second language's morphology, syntax, and semantics, adults appear to be more efficient than children (Snow & Hoefnagel-Hohle, 1978). But the long-range outcome is just the reverse. After a few years' exposure, young children speak the new language fluently. Differences between native-born and young second language learners typically cannot be detected except under stringent laboratory tests (e.g., for phonetic discrimination; Pallier, Bosch, & Sebastian-Galles, 1997). This contrast has been drawn by investigators who studied the outcome of second language learning as a function of age at first exposure (Johnson & Newport, 1989;

Oyama, 1978). In the Johnson and Newport study, the subjects were native Chinese and Korean speakers who came to the United States and were immersed in English at varying ages. These subjects were tested after a minimum of 5 years living in the English-speaking American community. Subjects listened to English sentences half of which were ungrammatical, the other half being the grammatical counterparts of these. Correct assignment of these sentences as grammatical versus ungrammatical was native-like for those exposed to English before about age 7. Thereafter, there was an increasing decrement in performance as a function of age at first exposure. These results have usually been interpreted as suggesting a critical period for language acquisition: an effect attributable to the mental status of the learner rather than to the environmental conditions for learning.

However, based on the data just discussed, an entirely different kind of explanation is possible: Perhaps exposure to Mandarin or Greek affects learning or organizational biases relevant to language and so interferes with the later learning of a different language. There must be some merit to this alternative hypothesis, otherwise there would be no explaining why Greeks and Chinese and Germans have different accents and different grammatical difficulties in acquiring English. The analysis of speech is context- and knowledge-dependent; therefore having the wrong knowledge should cause trouble with the analysis of foreign linguistic data.

Newport, Supalla, and their colleagues have over the past decade and a half studied populations which permit a disentangling of age or critical period effects from the effects of prior language learning. The subjects are the language-isolated deaf children of hearing parents who were discussed in Section III. Though these children generate idiosyncratic “home sign” systems that reveal the skeletal hallmarks of all human languages, this is by no means a situation equivalent to acquiring a fully elaborated language from native-speaking or -signing adults. As they grow up, most of these children eventually come into contact with a formal sign language; at that point they ordinarily enter the deaf community and use sign language daily and habitually for the rest of their lives. Newport (1990) studied the production and comprehension of American Sign Language (ASL) by adults who had been using ASL as their primary means of communication for at least 30 years, but whose first exposure was either from birth (children of deaf, signing parents), early in life (between ages 4 and 6), or late (after age 12). Only the early learners showed native competence thirty years later. Later learners had particular trouble with the ASL equivalents of function morphemes and the embedding structures of complex sentences (see also Mayberry, 1994). The same pattern emerges in the acquisition of Nicaraguan Sign Language by its first generations of speaker/inventors (see Section III): Senghas and Coppola (in press) found effects of signers' age of entry into the signing community on their use of aspects of NSL morphology. During NSL's development as a language, learners who started young were more likely to acquire the spatial morphological resources of this emerging system.

In short, late learning, whether of a first or a second language, leads to non-native competence. In both cases, the universal skeletal forms of language--the meanings of content words and their combination in spelling out basic predicate argument structures--are acquired, but the frills and gracenotes of elaborated languages are evidently more fragile and grow progressively harder to attain with the passage of time. Language learning, as we have tried to show, is robust to all the environmental variation compatible with the maintenance of human life, but reaches its apogee in the very young human learner.

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