

## Using Sound to Solve Syntactic Problems: The Role of Phonology in Grammatical Category Assignments

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One ubiquitous problem in language processing involves the assignment of words to the correct grammatical category, such as noun or verb. In general, semantic and syntactic cues have been cited as the principal information for grammatical category assignment, to the neglect of possible phonological cues. This neglect is unwarranted, and the following claims are made: (a) Numerous correlations between phonology and grammatical class exist, (b) some of these correlations are large and can pervade the entire lexicon of a language and hence can involve thousands of words, (c) experiments have repeatedly found that adults and children have learned these correlations, and (d) explanations for how these correlations arose can be proposed and evaluated. Implications of these phenomena for language representation and processing are discussed.

One of the many problems that must be solved in language acquisition, comprehension, and production is how to assign words to the appropriate grammatical categories, such as noun and verb. In particular, during language acquisition children must learn the grammatical categories of their language and learn which words fall into these different classes. Thus, German children must eventually learn that /ihr/ is a pronoun (*ihr*), whereas English children must learn that the same sound is a noun (*ear*). During language comprehension, adults also must classify words into grammatical classes quickly (i.e., in a fraction of a second) and accurately. Furthermore, the correct classification might not be immediately clear to the listener. For instance, *The team bats . . .* could correspond to an article-adjective-noun structure or an article-noun-verb structure, and the listener may have to wait for further information before making a classification decision. Finally, during language production, speakers must access words of the appropriate grammatical class to formulate an acceptable utterance. General success at this task is illustrated by the fact that speech errors seem to be strongly constrained by grammatical category. For example, inadvertent word substitutions, such as saying "apartment" instead of "appointment," almost always preserve grammatical class (Fay & Cutler, 1977; see also Garrett, 1982).

Investigations of these problems have focused much attention on the sources of information available for making grammatical category assignments. In general, such investigations focus almost exclusively on semantic and syntactic information for grammatical class. The semantic approach argues that major grammatical classes are universally associated with certain

semantic features. For example, nouns tend to denote concrete objects, whereas verbs denote readily perceived actions. Although these correlations are not perfect, grammatical classes may still be organized around prototypes that have the standard semantic features (Bates & MacWhinney, 1982; Schlesinger, 1974, 1988). Syntactic approaches, on the other hand, attempt to define grammatical classes in terms of distributional criteria. Thus, English nouns, but not other parts of speech (e.g., adjective *big*, verb *carry*, and adverb *quickly*), can appear in the structure *The \_\_\_\_\_ visited the zoo*. Verbs, on the other hand, can appear in *He will \_\_\_\_\_ the newspaper*, whereas nouns, adjectives, adverbs, and so on cannot (Maratsos, 1983; Maratsos & Chalkley, 1980).

Although many articles and experiments have explored the relative importance of semantic and syntactic information for grammatical class, the domain of phonology has been virtually ignored. For example, Maratsos (1983), in his major review of early grammatical development, allocates only four paragraphs to phonological information for grammatical class, whereas 30 pages are devoted to the semantic and syntactic domains. In the index to a more recent edited work that focuses in large part on grammatical category acquisition (Levy, Schlesinger, & Braine, 1988), only a single page reference is listed under the heading "phonological," whereas semantic and syntactic headings each receive over 50 page references.

This neglect is not due to the fact that phonology has been seriously considered, found to be wanting, and then rejected. Instead, assumptions about the nature of language structure and processing might have inhibited intense examination of phonological cues to grammatical class. In particular, the structure of language is generally described as a system of rules that provides necessary and sufficient information about the components of the linguistic domain and their interactions. Furthermore, knowledge of language can be represented in terms of such rules, which are brought to bear in making decisions about language structure, such as judgments of grammaticality and grammatical category assignments. Thus, in the sentence *The team bats are clinging to the roof of the stadium*, distri-

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butional rules of English are sufficient to determine that *bats* is a noun and *clinging* is a verb. Other correlates with grammatical class would be both less reliable than syntactic information and unnecessary. Semantic correlates might be an exception given their universality and hence possible role as the conceptual foundations of grammatical classes (Hopper & Thompson, 1984; Langacker, 1987). However, any phonological correlates of grammatical classes are likely to be rare, unreliable, and language specific and hence, not very important to grammatical category assignment.

Although reasonable, this conclusion is not necessarily true because domains of human perception exist in which probabilistic information is used even though other information that is sufficient to solve particular tasks is available. For example, one of the major problems in visual perception is the construction of a three-dimensional representation of the environment from a two-dimensional pattern. An important step in trying to understand this problem has been to identify the sources of optical information that could predict three-dimensional structure. Through the centuries, many possible information sources have been found, including stereopsis, motion parallax, relative size, and height in the projection plane (see Pastore, 1971, for historical discussion). After identifying these sources, one must determine which ones are actually used in depth perception, along with their various weights and priorities. One possible hypothesis about information use corresponds with what Bruno and Cutting (1988) called *selection* or the situation in which "observers . . . use the single most effective available source and disregard the others" (p. 162). For example, a lawful relation exists between distance and motion parallax, and so this information could be relied on to determine distance, with other probabilistic cues being ignored. This scenario is analogous to the problem of grammatical category assignment, with *rule* replacing *law*. Thus, rules of syntactic structure can provide perfect information about the grammatical class of a word, and it may be reasonable to suppose that imperfect phonological correlates to grammatical class would be discounted, perhaps not even learned. In the case of visual depth perception, however, the selection strategy appears to be incorrect. For example, Bruno and Cutting examined the extent to which motion parallax, occlusion, relative size, and height in the projection plane influenced depth judgments. Under a selection hypothesis, one might expect that motion parallax alone would be considered given its more lawful relation to distance than relative size or height in the plane. However, using a variety of experimental methods, Bruno and Cutting found that all of these variables were weighed in distance judgments. This pattern held even when motion parallax was present in the display. In fact, the weight given to the probabilistic cue of height in the projection plane was not significantly different from that given to motion parallax, although Bruno and Cutting emphasize that the exact weights could change with viewing conditions.

One might object to this example because the probabilistic cues to depth are consequences of geometry that hold for all observers and hence might be part of an innate visual processing system. They would therefore be analogous to universal semantic correlates of grammatical class. However, other examples can be cited in which probabilistic information is exploited that appears to be unnecessary to solve a problem and is cer-

tainly not universal. One such example comes from the domain of language processing itself. Under conditions of brief stimulus presentation, written letters can be identified with higher accuracy if they are presented within a word context rather than in isolation (McClelland & Rumelhart, 1981; Reicher, 1969). Thus, the letter *k* is identified with greater accuracy if it appears in the context of *work* than if it appears alone. This facilitation holds even though the visual features of the clearly printed *k* are in principle sufficient for identification. However, when this information must be rapidly registered and processed, the likelihood of incomplete encoding increases. Additional information from the word context facilitates this encoding and so is useful in that it permits high processing speed while minimizing error rates. The additional information used in this letter identification task is certainly probabilistic in nature given that words other than *work* begin with *wor*, such as *word*, and *worm*. The information is also language specific because *work* need not be an actual word in other languages.

These depth perception and letter identification examples indicate that one should not necessarily conclude that phonological information for grammatical class is ignored even if it is probabilistic. The existence of and sensitivity to such information could facilitate a number of language processing tasks. For example, utterances are rarely heard in perfect listening conditions, and hence syntactic information for grammatical class might not be perfectly registered. Additional phonological cues, even though also present in noise, might assist disambiguation. In addition, listeners must make grammatical category assignments rapidly, and, like the letter identification task described above, speed-accuracy tradeoffs might be minimized if syntactic information is supplemented with probabilistic phonological cues to grammatical class. A similar possibility exists in language production, in which speakers must retrieve words from memory at a rate that permits a typical conversational pace of 150 words per minute (Maclay & Osgood, 1959). Phonological information may be used in conjunction with planned syntactic frames to restrict retrieval operations to the appropriate grammatical class. Finally, children must not only assign words to grammatical classes in a sentence context but also store in memory the grammatical classes of words so they can use them correctly in the future. Perhaps phonological features that are partly diagnostic of grammatical class increase the speed and accuracy of this memorization.

Speculations about these possibilities, much less experimental investigations, require that certain prior issues be answered. The first issue concerns information availability. Do phonological cues to grammatical class exist? How widespread are these correlations within a language, and what are their individual magnitudes? Given that phonological information to grammatical class exists, the second issue to be addressed is human sensitivity. Do people of different ages have knowledge of this information? The third issue involves the distinction between information sensitivity versus exploitation. Given that human beings have learned phonological cues to grammatical class, do they actually exploit those cues in ongoing language processing? For example, are nouns that conform with a phonological pattern typical of their class learned faster than nouns that violate this pattern? This article addresses the first 2 issues—in-

formation availability and sensitivity—while leaving open the question of exploitation. At present, a variety of evidence can be brought to bear on the former issues, whereas little pertinent evidence currently exists for the exploitation question. The first section of this article, therefore, describes a number of documented correlates to grammatical class as well as any knowledge that human beings are sensitive to them. The second section describes and evaluates some explanations for how these various correlations arose in the first place. The final section discusses the implications of these phenomena for understanding various topics in language representation and processing.

### Phonological Correlates of Grammatical Class: Where Are They and Who Knows Them?

In this section, I describe a number of correlations between phonology and grammatical class. Where relevant evidence exists, knowledge of these correlations in adults, children, or both is discussed. Most of the emphasis is on English, which is a weakness at present because the scope of the phonological approach to grammatical category assignment will depend on the presence of phonology–grammatical class correlations across languages. Furthermore, the specific correlations cited with regard to English should not be considered generalizable to other languages. They may turn out to be specific to English. Thus, phonological correlates to grammatical class in other languages may take different forms. Some may consider the language specificity of these correlations to undermine a phonological approach to grammatical category assignment. Later in the article, the validity of this concern is discussed. Finally, some of the relationships described in this article are quite reliable and could play individually important roles in grammatical category assignments. Others are small and possibly less important. However, they are discussed because evidence indicates that people have learned even small, local patterns, and hence have keen sensitivity to phonological cues to grammatical class. Also, although some of these correlations are individually small, they might provide stronger constraints on the grammatical class of a word when considered jointly.

#### *Stress and Grammatical Class in English*

One well-known phonological feature that distinguishes English nouns from verbs is stress (cf. Liberman & Prince, 1977; Sherman, 1975, for further discussion). In particular, disyllabic English nouns are more likely to receive first-syllable stress, whereas disyllabic verbs are more likely to receive second-syllable stress. This difference is best illustrated through noun–verb homographs, such as *record* which are historically and semantically related, and which possessed the same stress pattern at one time in the history of English (Sherman, 1975). However, their stress patterns subsequently diverged, with the noun being stressed on the first syllable, as in *I gave the record to my friend*, and the verb being stressed on the second syllable, as in *John recorded the concert*. This stress difference is both reliable and widespread throughout the English lexicon. For example, among noun–verb homographs that differ in stress, such as *contrast*, *permit*, and *compound*, not a single case exists in which the noun has second-syllable stress but the verb has first-

syllable stress (Sherman, 1975). In one representative sample of over 3,000 nouns and 1,000 verbs, Kelly and Bock (1988) found that 94% of the nouns had first-syllable stress, whereas 69% of the verbs had second-syllable stress. Furthermore, within the sample, 90% of words with first-syllable stress were nouns rather than verbs, whereas 85% of words with second-syllable stress were verbs rather than nouns. This latter value is more meaningful because the listener's task is to infer grammatical class from a given stress pattern rather than the reverse. Finally, historical analyses have documented that the noun–verb stress difference extends far back into English history and has grown stronger through the centuries (Sherman, 1975).

A number of experiments have indicated that adult English speakers have implicit knowledge of the noun–verb stress difference. Kelly and Bock (1988) asked subjects to read aloud target sentences, each of which contained a disyllabic pseudoword acting as a noun or a verb. Subjects were more likely to pronounce pseudowords with first-syllable stress if they acted as nouns rather than verbs (see also P. T. Smith & Baker, 1976). In Kelly (1988a), native English speakers were presented with tape-recorded disyllabic pseudowords that varied in whether they were stressed on the first or second syllable. The subjects were simply asked to create a sentence containing the target pseudoword. The basic rationale was that if subjects had knowledge of the noun–verb stress difference, and they implicitly classified the pseudowords into grammatical categories based on the typical stress patterns of nouns and verbs, then the subjects should tend to use the pseudowords more often as nouns when they had first- rather than second-syllable stress. The probability of verb use should have correspondingly increased when items received second- rather than first-syllable stress. These predictions were borne out in the experiment.

A second study by Kelly (1988a) took advantage of the fact that nouns and verbs often shift grammatical classes. Thus, *patrol* originated in English as a noun but subsequently developed a verb use, whereas *fumble* originated as a verb and later developed a noun use. English speakers should therefore be quite comfortable with using nouns as verbs and vice versa, and even 3-year-old children make such category extensions (Clark, 1982). The question investigated was whether the stress patterns of nouns and verbs could influence the likelihood of category transfer. In particular, would a word be more likely to switch into a different grammatical class if it possessed the standard stress pattern of that class than if it did not? One group of subjects was presented with pairs of disyllabic nouns differing in stress, such as *gazelle* and *llama*. None of the nouns had verb uses in current English according to a recent dictionary. In addition, the nouns in a pair were drawn from the same semantic category (e.g., animals, cities) and did not differ in prototypicality within that category or in their frequency of usage as nouns. Another group of subjects was presented with pairs of disyllabic verbs differing in stress, such as *beseech* and *grovel*. None of the verbs had noun uses in current English, and they did not differ in verb frequency. Subjects in the noun group were asked to select one member of each pair and use it as a verb in a sentence, whereas subjects in the verb group were asked to select one member of each pair and use it as a noun in a sentence. The subjects showed sensitivity to the noun–verb stress difference in their choices, as they were more likely to

select nouns for verb use if they had the prototypical verb stress marking and verbs for noun use if they had the prototypical noun marking.

Finally, Kawamoto, Farrar, and Overbeek (1990) showed that rapid, on-line classification of words into grammatical categories was affected by stress. In their experiment, subjects named disyllabic nouns in sentence contexts more rapidly if the nouns had first- rather than second-syllable stress. Disyllabic verbs, on the other hand, were named more rapidly if they had second- rather than first-syllable stress. Thus, multiple tasks and measures strongly confirm that adult English speakers have knowledge of the noun-verb stress difference.

### *Syllable Number and Grammatical Class in English*

Given the existence of adult sensitivity to the English noun-verb stress difference, the next question seems to be whether children also might have learned the distinction. Such knowledge could conceivably assist the child in assigning novel words to the correct grammatical class. However, analyses of parental speech revealed no noun-verb stress difference in the types of words used by English-speaking parents to their 2-year-old children. The reason for this absence was clear: The vocabulary experienced by the 15-month-old children in our sample contained very few polysyllabic verbs. Polysyllabic nouns, on the other hand, were fairly common. More extensive analyses conducted by Cassidy and Kelly (1991) revealed that a relationship between syllable number and grammatical class did in fact exist in English parental speech, with nouns generally containing more syllables than verbs. Indeed, the relationship was monotonic such that as a word's syllable number increased, the probability that the word was a noun increased, whereas the probability that it was a verb decreased. In particular, the probabilities that one, two, three, and four syllable words were nouns rather than verbs were 38%, 76%, 92%, and 100%, respectively. The relationship between syllable number and grammatical class was reliable, as it appeared under a variety of scoring criteria, the most significant being those that counted syllabic inflections like *-ing* as belonging to the stem. Because verbs are more likely than nouns to receive such syllabic inflections (see Kelly, 1988b, for estimates of the strength of this difference), counting them as part of the stem would tend to increase the mean syllable number of verbs more than of nouns. However, even in this analysis, which attributes no knowledge of the stem-inflection distinction to children, the monotonic relationship between syllable number and grammatical class remained highly significant. Finally, the same pattern was found in the speech of all 10 of the mothers in the sample regardless of the scoring system used, which suggests that the noun-verb syllable difference is an invariant feature of the linguistic environment of a future English-speaking child.

Of course, the correlation between syllable number and grammatical class might be an idiosyncrasy of parental speech and not a reflection of general characteristics of the English language. If so, attention to the correlation would not assist language acquisition and might even prove a hindrance. However, analyses of adult English revealed the same pattern, once again under a variety of scoring criteria. Thus, the patterns uncovered in parental speech are, in fact, representative of

those present in the general English vocabulary. Finally, Cassidy and Kelly (1991) found that the syllable number difference between nouns and verbs extends far back into English history. In particular, they examined words entering English between the twelfth and twentieth centuries and found that nouns contained significantly more syllables than verbs in each century examined. Thus, syllable number could have provided information for grammatical class to many generations of people learning and speaking English.

Two experiments support the view that adults have knowledge of the noun-verb syllable difference. In one recently completed study, subjects were presented with written versions of monosyllabic or trisyllabic English words, such as *smirk* and *boomerang*. The words were randomly selected except for the constraint that each word be used equally often as a noun or a verb as measured by the Francis and Kucera (1982) word frequency norms. The subjects were asked whether the word on each trial was more frequently used in English as a noun or a verb, and they judged the trisyllabic words to be more frequently used as nouns and the monosyllabic words to be more frequently used as verbs. This pattern would be predicted if trisyllabic words were closer to the prototypical noun representation and monosyllabic words were closer to the prototypical verb representation. One potential problem with this experiment, however, is the possibility that subjects were relying on the meanings of the target words in their decisions. Because syllable number is correlated with grammatical class, and the latter is correlated with semantic features such as action and object, the subjects may have been relying directly on semantics rather than syllable number. Thus, *boomerang* may have been classified as a noun because it refers to a concrete object and not because it has three syllables. In another experiment, therefore, Cassidy and Kelly (1991) tape-recorded sets of mono-, bi-, and trisyllabic pseudowords and then presented them to subjects, who were asked to construct a sentence containing the pseudoword that they heard on a given trial. Stress patterns of the polysyllabic words were counterbalanced to control for known correlations between stress and grammatical class in English. The dependent measure was the grammatical class that the subjects assigned to the word, which could be determined from the sentence context. The grammatical usage patterns matched those found in the English lexicon: As the syllable number of the pseudowords increased from 1 to 3, the probability of verb use decreased, whereas the probability of noun use increased.

To test whether young children also associate syllable number differences with grammatical class (or the semantic correlates of grammatical class, such as objecthood and actionhood), Cassidy and Kelly (1991) showed 3-year-olds simple videotaped scenes containing a familiar object performing an action, such as an electric car driving in a circle or a kite flying. The children were introduced to a puppet who liked looking at the shows and would view them with the child. The puppet did not speak English but only a strange puppet language, and the child was asked to guess what the puppet was talking about when he used certain words. On each trial, the experimenter told the child that whenever the puppet saw the videotape currently being displayed, it said "x," where *x* was either a monosyllabic or a trisyllabic pseudoword. The child was asked to guess what the puppet meant by *x*, and the object and action were named as

the possible choices, with all the object and action words being monosyllabic. The child's choices were significantly affected by the syllable number of the pseudoword, with object referents being chosen more often for the trisyllabic than for the monosyllabic pseudowords. This result does not necessarily mean that children assume that a correlation exists between syllable number and the grammatical classes noun and verb. Rather, children might as yet only assume that a correlation exists between syllable number and certain semantic notions, such as object and action, which are themselves correlated with grammatical class. However, given the intercorrelations between syllable number, semantics, and grammatical class, attention to the former two variables will in practice implicate the third, as action words would ultimately be treated as verbs and object words as nouns.

### *Word Duration and Grammatical Class in English*

One of the major cuts in the lexicon divides so-called open-class items from closed-class items. This division has been accorded great theoretical weight, as it has been implicated in accounts of aphasia (Kean, 1979), the organization of the mental lexicon (Bradley & Garrett, 1983), and language acquisition (Brown, 1973). Members of the open class consist of major lexical categories, like nouns and verbs, that can readily admit new members in the history of a language. Members of the closed class, on the other hand, consist of functional categories like articles and prepositions. These categories strongly resist the admission of new members. Furthermore, the open and closed classes have been distinguished acoustically through relative stress, with the former being considered stressed and the latter unstressed. Gleitman, Gleitman, Landau, and Wanner (1988) have argued that this stress difference might be used by children to identify open and closed class items.

The role of stress in general, and its phonetic correlates in particular, might help to make more fine-grained grammatical distinctions. In particular, stress systems in English and other languages are not binary but consist of multiple levels (Chomsky & Halle, 1968). Hence, one might expect gradations of stress to exist even within the open- and closed-class vocabularies. For example, though nouns and verbs are both considered stressed, nouns are more likely to occupy stressed positions in the lines of traditional English poetry (Kelly & Bock, 1988). Some evidence from analyses of more ordinary speech indicates that English nouns and verbs differ in duration, an acoustic correlate of stress. Sorenson, Cooper, and Paccia (1978) asked subjects to read typical sentences of English. The durations of target monosyllabic nouns and verbs were then measured, and the nouns were significantly longer than the verbs. These differences appeared even for the noun and verb versions of homonyms like *coach*. The duration of *coach* was longer when it was used as a noun rather than a verb. Sorenson et al. attribute this difference to the fact that English nouns are more likely than English verbs to appear phrase and clause finally, and hence to undergo lengthening effects concomitant with phrase and clause boundaries. As evidence for this interpretation, they show that the noun and verb versions of homonyms do not differ in duration when they both occur clause finally. Another contextual difference between nouns and

verbs might also conspire to create durational differences between the two classes. In particular, English verbs are more likely than English nouns to receive syllabic inflections, and studies have shown that adding an extra syllable onto a target syllable will decrease the target's duration (Lehiste, 1970). Because verbs are more likely than nouns to receive such extra syllables, they will undergo greater durational shortening in typical speech contexts. In recently completed experiments, we have obtained evidence that verb durations are in fact diminished by the addition of syllabic inflections. We have also replicated Sorenson et al.'s study of clause final lengthening effects on nouns and verbs using more naturalistic speech samples (Davis, Morris, & Kelly, 1992).

At present, the noun-verb duration difference has only been reported in sentence contexts. Indeed, because Sorenson et al. (1978) did not find duration differences when nouns and verbs occurred clause finally, context-free differences might not exist. Even if the noun-verb duration difference appears only in sentence contexts, however, it could still provide useful information for grammatical class. Indeed, given the fact that parental speech to children typically exaggerates the prosodic patterns of the adult language (Fernald & Simon, 1984), the durational difference between nouns and verbs could be quite large. Thus, parents exaggerate clause final lengthening effects considerably, and so would presumably greatly lengthen the durations of nouns relative to verbs. We are currently testing this possibility by analyzing the durations of monosyllabic nouns and verbs in parental speech and correlating those durational measures with syntactic boundary measures. In addition, we are exploring whether or not English speakers have implicit knowledge of the duration cue to noun and verbhood.

### *Vowel Epenthesis in the -ed Inflection*

The highly frequent *-ed* inflection in English varies in its pronunciation. When appended to words ending in dental stops, it must be pronounced syllabically (e.g., *recorded* and *permitted*). For almost all other words, the inflection is pronounced nonsyllabically, with the exact pronunciation depending on whether the immediately preceding consonant is voiced or voiceless. However, with some words that do not end in /d/ or /t/, the vowel either must be pronounced or its pronunciation is optional. In current English, these words are invariably adjectives. Thus, the *-ed* of *ragged* must be pronounced with a vowel when it is used as an adjective, as in *John wore his ragged shirt*, but not when it is used as a verb, as in *John ragged on his little sister*. With other words, the vowel pronunciation is optional, but only in certain grammatical uses (see Marchand, 1969, for further examples). Thus, when *learned* is used as an adjective, one can say "The researchers were surprised at the learned/learned behavior of the rat." The syllabic and nonsyllabic versions of *learned* obviously differ in meaning as well as pronunciation, with the former implying a more schooled rodent. However, vowel epenthesis in the *-ed* inflection cannot occur when *learned* is used as a verb (e.g., *The rat learned to press the bar* vs. \**The rat learned to press the bar* or even \**The educated rat learned to press the bar*).

Kawamoto and Farrar (1990) have demonstrated that English speakers have knowledge of the relation between grammatical

class and vowel epenthesis with *-ed*. They asked speakers to read aloud sentences containing a target pseudoword appended with *-ed*. The pseudoword acted as an adjective (e.g., *The ocean's pelled beaches slowly erode*) or a verb (e.g., *The ocean pelled beaches slowly*), with surrounding rhythmic context controlled. Whereas vowel epenthesis did occur with adjective uses, though rarely, it never occurred with verb uses of the target words. The ability to elicit epenthesis with pseudowords that lack stored lexical entries indicates that the epenthesis phenomenon with *-ed* remains somewhat productive in current English speakers, contrary to claims (Marchand, 1969) that it is only associated with particular words.

The vowel epenthesis cue to grammatical class is admittedly weak, although the fact that speakers have nonetheless learned about it testifies to human sensitivity to these phonology-grammatical class correlations. The vowel epenthesis cue was much stronger in earlier periods of English (Minkova, 1985) and so may have been more useful to English speakers of the past than of the present. Of course, the erosion of such phonological cues raises doubts about their usefulness. After all, if such cues were important to grammatical category assignment, they would presumably be resistant to such extinction. However, such resistance might be dampened if other cues to grammatical class were increasing in reliability during the same time period. For example, the stress cue to grammatical class has been increasing in strength through the centuries (Sherman, 1975) and may have compensated for the loss of other information. This example illustrates the difficulty involved in making predictions about how language structure might in general change through time. The scope of the variables involved in language change renders conclusions drawn from a single variable somewhat suspect (see Labov, 1972, for further discussion).

### *Voicing and Grammatical Class Distinctions*

One articulatory dimension that can distinguish between consonant phonemes is whether or not the vocal cords vibrate during production of the consonant, or how soon vocal cord vibration begins after the initiation of the consonant. For example, /z/ and /s/ agree on all articulatory dimensions except voicing, with the former being voiced and the latter unvoiced. The phonemes /b/ and /p/ differ in that vocal cord vibration begins earlier in the production of /b/ than /p/. The voicing variable is partially predictive of grammatical category in English, and speakers are sensitive to at least some of these relationships. For example, word initial *th* can be pronounced with or without voicing, depending on the particular word involved. Moreover, the pronunciation can be predicted very strongly by the grammatical class of a word, with words from open-class categories like nouns (e.g., *thing*), verbs (e.g., *think*), and adjectives (e.g., *thick*) pronounced with voiceless *th* and words from closed-class categories like articles (e.g., *the*), complementizers (e.g., *that*), and pronouns (e.g., *they*) pronounced with voiced *th*. Campbell and Besner (1981) have shown that adult English speakers have knowledge of this correlation. They presented speakers with sentences containing nonsense words beginning with *th*. The nonsense words acted as members of open- or closed-class categories. Subjects read the sentences aloud, and their pronunciations of *th* were classified as voiced or voiceless

on the basis of spectrographic analysis and the judgments of trained phoneticians. The grammatical usage of the nonsense word strongly influenced pronunciation, with closed-class words being pronounced more often with voiced *th* and open-class nonsense words with voiceless *th*.

The voicing variable is also partly predictive of whether an English word is a noun or a verb, though no experiments have documented knowledge of this pattern on the part of English speakers. In some historically related, and often homographic, noun-verb pairs, the final phoneme differs solely along the voicing dimension, with the noun version voiceless and the verb version voiced. Homographic examples include *use*, *abuse*, and *house*. Historically related pairs that differ slightly in spelling include *teeth* versus *teethe* and *wreath* versus *wreathe*.

### *English Noun and Verb Vowel Types*

In a lexical analysis of the Francis and Kucera (1982) word frequency norms, Soreno and Jongman (1990) found that the stressed syllables of nouns tended to contain back vowels (e.g., *school*) more than front vowels (e.g., *street*), whereas the opposite pattern held for verbs. This difference only appeared for high-frequency words, in this case words with frequencies of 250 per million or greater. However, its presence in the most frequent words of English indicates that the vowel difference between nouns and verbs has a high word token frequency, if not word type frequency. Using lexical decision and noun-verb classification tasks, Soreno and Jongman found evidence that English speakers are sensitive to this correlation between vowel type and grammatical class. For example, nouns were classified more rapidly if they contained back vowels rather than front vowels, whereas the opposite pattern emerged for verbs. (The interaction between vowel type and form class was significant, but significance values for each grammatical class considered separately were not reported). Interestingly, these reaction time patterns appeared only for high-frequency nouns and verbs, perhaps suggesting that speakers are sensitive not only to the main effect of vowel type in predicting grammatical category but also to interactions between this variable and word frequency. However, this conclusion rests on the prediction and attainment of a null effect of vowel quality for low-frequency words. Given the difficulties involved in interpreting such effects, the strongest conclusion warranted at this point is that English speakers have some implicit knowledge of the vowel differences between nouns and verbs.

### *Phonological Distinctions Within a Grammatical Class*

Thus far, various types of information have been cited that serve to distinguish words from different grammatical categories. However, certain phonological cues could be associated with subsets within a single category. For example, English makes use of two dative structures: the prepositional, as in *Cheryl threw the ball to Shelley*, and the double object, as in *Cheryl threw Shelley the ball*. Although *throw*, *give*, and many other verbs can appear in both constructions, some verbs are permitted in one but not the other. In addition to certain semantic factors (see Pinker, 1989, for summary), the phonological structure of a verb influences the ease with which it can

appear in the dative alternation. In particular, both syllable number and stress affects the acceptability of a verb in the double object form. Thus, monosyllabic verbs sound more natural than polysyllabic verbs in the double object structure. So, *John gave/donated the book to the committee* sounds perfectly grammatical. However, whereas *gave* remains acceptable in the double object construction, *donate* sounds awkward at best: *John donated the committee the book*. Polysyllabic words are more acceptable when they have stress on the first rather than the second syllable. For instance, *John offered Mary a seat* is grammatical, whereas *John obtained Mary a seat* is not (Green, 1974; Mazurkewich & White, 1984; Pinker, 1989).

Both adult and child speakers of English seem to have learned the syllable number restriction on the dative alternation. For example, Gropen, Pinker, Hollander, Goldberg, and Wilson (1989) asked adults to rate the acceptability of various sentences, which included prepositional and double object forms. All of the sentences contained a pseudoword acting as a verb, with the pseudoword containing either one or three syllables. Syllable number influenced acceptability judgments for double object datives in the predicted manner, with trisyllabic words being rated less acceptable in that construction. However, syllable number did not influence the ratings for prepositional dative structures, indicating that polysyllabic verbs in general are not less acceptable in sentences. This control is important given the fact that verbs as a class tend to contain few syllables, and hence syllable number might be inversely correlated with verb acceptability across all constructions equally. Syllable number may have a general impact on verb acceptability (Gropen et al. only report results for two constructions), but the strength of this impact appears to interact with type of construction in a predictable manner.

### *Phonological Cues to Grammatical Gender*

In languages such as French and German, nouns are divided into different classes that require different grammatical markers for such notions as case and definiteness. For example, German has three nominative case, singular number analogues of the English definite article *the*, namely, *der*, *die*, and *das*, and nouns are obligatorily required to receive the correct article in appropriate contexts. These noun classes are traditionally called *gender* categories because male and female referents are denoted with different gender markers. However, these semantic correlates of gender are notoriously unreliable. For example, inanimate objects are often denoted with masculine or feminine gender markings rather than neuter. In addition, inanimate objects with male or female connotations are not generally correlated with the expected gender classification. Perhaps because semantic correlates of gender categories are weak, researchers have been more willing to search for phonological correlates of these grammatical categories rather than correlates of major lexical categories like noun and verb, which have been more easily associated with semantic notions. As a result, evidence from a variety of languages has been gathered to show that phonological cues to gender classes exist and that speakers are sensitive to them. In this section, I review evidence from some of these languages.

*French.* Tucker, Lambert, Rigault, and Segalowitz (1968)

demonstrated that the masculine and feminine gender categories of French can be predicted quite strongly by the ending patterns of words and, to a lesser extent, by the beginning patterns. For example, masculine nouns tend to end in *-ais* and *-oi*, among others, whereas feminine endings tend to end in *-ssion* and *-stion*. The number and strength of these predictors is impressive: Among 14 ending patterns examined, 10 had greater than 90% success at predicting whether a word was masculine or feminine. Interestingly, these correlations, although strong, had not been noticed by the French grammarians consulted by Tucker et al., who claimed that "there are no regularities or only minimal ones to gender determination" (p. 316). Nonetheless, despite conscious ignorance of these strong regularities on the part of adult experts (and, presumably, the general population of French speakers), even children appear to have learned them. Thus, Tucker et al. presented French-speaking children between 8 and 16 years old with rare or invented nouns that they had to classify as masculine or feminine by picking the appropriate indefinite article *un* or *une* for each noun. The children's choices were clearly influenced by the endings of the target words. Indeed, across the various conditions of the experiment, children were significantly sensitive to every ending that reliably signaled whether a noun was masculine or feminine. Furthermore, their responses were also modified in appropriate ways by the beginnings of words, when these were also correlated with grammatical class. Because even instructors of French grammar have not identified these relations, children obviously learn them without formal training (and in fact have no conscious knowledge of these phonological cues either, according to Karmiloff-Smith, 1979). Hence, the ability of the children to learn these correlations should not be considered an unusual or artificial phenomenon in language acquisition.

*Hebrew.* As with French, at least some descriptions of Hebrew grammar assume that "the gender of objects is arbitrarily assigned" (Hetzron, 1987, p. 699), aside from the fact that the true gender of animate objects determines the gender of the nouns used to denote them. However, certain phonological clues can in fact reliably indicate whether a noun is masculine or feminine, the two gender categories used in Hebrew. In particular, word final /a/ or /t/ strongly predicts that a noun is feminine, although exceptions do exist. Levy (1983) has shown, in both longitudinal and cross-sectional studies, that children learning Hebrew use this phonological cue to determine gender class. For example, children will treat masculine nouns as feminine if they end in the typical feminine phonemes. Furthermore, the children showed little evidence of using conceptual gender to assign nouns to the masculine or feminine classes. Thus, they did not base their nominal gender classifications on whether the referent of a noun had male (e.g., *pipe*) or female (e.g., *dress*) associations. Such results suggest that researchers should not simply assume that semantic factors always dominate phonological factors in the acquisition and use of gender classes.

*Russian.* Russian has three gender categories, which are partly predicted by semantic gender. In addition, the sound patterns on the ends of words are also correlated with these gender classes. Feminine nouns generally end in the vowel *-a*, though important exceptions exist, such as *papa*, *dyadya*, and *dedushka*, which respectively mean father, uncle, and grandfa-

ther. Neuter nouns tend to end in the vowel *-o*, and masculine nouns tend to end in consonants. Children learning Russian detect these phonological correlations by three years of age or earlier. Thus, masculine nouns are more likely to be treated as feminine if they end in *-a* than if they end in a consonant (Popova, 1973). Furthermore, these patterns are found even for nouns like *papa*, which have a strongly masculine meaning but have the standard feminine ending. For similar findings on the acquisition of Latvian, see Ruke-Dravina (1973).

*German.* As with Russian, German uses three gender categories which are correlated with semantic gender, although exceptions, such as neuter *das Mädchen* for girl, exist. In addition, semantic factors are not strong predictors of the gender class of inanimate nouns, although some patterns exist (e.g., words denoting alcoholic drinks tend to be masculine). Phonological cues to gender are not explicitly obvious, prompting Maratsos and Chalkley (1980) to claim that "There do exist some weak correspondences between gender class and the phonological . . . characteristics of terms, but only for a small number of German nouns . . . Most nouns are quite arbitrarily assigned" (p. 137). However, extensive analyses by Zubin and Köpke (1981) have revealed that a variety of phonological cues to German gender exist and that high accuracy can be achieved in placing German nouns in gender classes when these cues are used in concert. For example, masculine nouns are more likely than other nouns to be monosyllabic and to end in a fricative followed by a /t/. Feminine nouns tend to end in vowels, as in *die Pfeife* (pipe) and *die Schweinerei* (mess). In studies designed to elicit gender classifications for real and invented words, MacWhinney (1978) found evidence that children learning German were sensitive to some of these phonological correlates.

### Summary

A number of empirical conclusions can be drawn from the evidence discussed in this section. First, a wide variety of phonological correlates to grammatical class exists in English and, where analyses have been conducted, in other languages as well. Some of these relationships, such as that between stress and grammatical class in English, are highly reliable, whereas others are less consistent (e.g., final consonant voicing in English nouns and verbs), applicable to a limited range of words in the lexicon of a language (e.g., vowel quality differences between English nouns and verbs), or both. Second, experiments have repeatedly shown that adults and, to a lesser extent, children have implicit knowledge of these correlations (although every study that has tried to find child sensitivity has, in fact, found it). Indeed, sensitivity has been found for small as well as large relationships between phonological features and grammatical class. Nonetheless, one might wonder why such widespread sensitivity exists, particularly for very local cues like those that predict which verbs can undergo the English dative alternation. One possibility is that children and adults are not really attending to novel sources of information, that is, phonological structures that are useful solely for grammatical category assignment. Rather, many of these structures could be, and apparently are, used to solve other problems in language acquisition and processing. Thus, syllable duration can be used to locate phrase and clause boundaries in speech (Klatt, 1976;

Hirsch-Pasek et al., 1987; Streeter, 1978), and without some sort of bounding information, language learning may be impossible, at least judging from the results of artificial language experiments (Morgan, Meier, & Newport, 1987). Furthermore, syllable duration may be correlated with even finer details of syntactic structure, such as the height of constituent attachment in a phrase structure tree, and experiments indicate that listeners can use this information to determine the constituent structure of a sentence (Cooper, Paccia, & Lapointe, 1978). Acoustic correlates of perceived stress, such as syllable duration, could be useful in distinguishing given and new information (Fowler & Housum, 1987) and in finding word boundaries, because, with some languages at least, stressed syllables are consistently located at a particular point in a word (see Trubetzkoy, 1958/1969, for examples and Gleitman et al., 1988, for a discussion of the role of the stressed syllable in language acquisition). The number of syllables in a word is predictive not only of grammatical category, but also of certain semantic information, such as the prototypicality (Brown & Lenneberg, 1954) and visual complexity (Kelly, Springer, & Keil, 1990) of their referents. Finally, phoneme sequences at the beginnings and ends of words could be used to find word boundaries (see Trubetzkoy, 1958/1969, for examples). Thus, the phonological cues discussed in this article are not insular in their importance, but can help children and adults solve multiple linguistic problems. Indeed, their breadth of relevance may in part explain why they are apparently learned and exploited so easily. Billman (1983) has argued that learning a particular rule will be facilitated to the extent that the relevant variables appear in other rules and so provide broad assistance in learning. In terms of language acquisition and processing, a relatively few phonological variables could therefore go a long way in the discovery and use of linguistic structure.

### The Causation of Phonology–Grammatical Class Correlations

Given the prevalence of phonological correlates with grammatical class, and their potentially useful role in language acquisition and processing, one might initially suspect that languages are directly pressured to develop some phonological indices of grammatical class. However, a major problem with such an explanation is that it cannot predict the particular forms such indices take. Why is it, for example, that nouns contain more syllables than verbs in English rather the reverse? Why are English disyllabic verbs more likely than disyllabic nouns to have stress on the second syllable rather than the reverse? An alternative account might claim that these individual correlations arose through a number of possibly unrelated events but, once the correlations were established, could be exploited in language processing. This scenario for language evolution is similar to some accounts of biological evolution in which an anatomical structure originally evolved to serve one function but was later confiscated to facilitate another function. An often-cited example concerns avian feathers, which originally participated in thermoregulation but were subsequently modified for flight. On observing their current utility, one might be inclined to suppose that feathers evolved directly for aerial locomotion. However, the actual history of the struc-

ture demonstrates that current function cannot necessarily be used to infer past causal pressures (Gould & Vrba, 1982). Similarly, the fact that phonological information is used to make grammatical category assignments does not entail that this information evolved to assist such assignments. They may have been caused by other factors, but, once present, could then be used to solve the grammatical category assignment problem. In Gould's (1983) terminology, such phonological correlates to grammatical class would be "exaptations" rather than "adaptations," or "structures that arose for other reasons [than their current utility], and then were fortuitously available for other usages" (Gould, 1983, p. 171).

Of course, even if phonological correlates to grammatical class arose through pressures distinct from the problem of assigning words to the correct grammatical class, one might still hope for general explanations that could encompass multiple correlations and which might apply cross-linguistically. In this section, I discuss such a general explanation as it applies to three correlations between phonology and grammatical class. Given the scope of this explanation, it may serve as a heuristic for searching for currently unknown correlations in English and other languages. In addition, the examples illustrate that explanations can be proposed that are specific enough to be subjected to experimental evaluation.

#### A General Mechanism for Phonological Differences Between Grammatical Classes

Earlier, I described a possible explanation for the longer durations of nouns compared with verbs in English sentences. First, because of the distributional nature of English, nouns are more likely than verbs to occur phrase and clause finally and to undergo lengthening effects characteristic of those syntactic boundaries. Second, verbs are more likely than nouns to receive syllabic inflections and hence to experience concomitant shortening effects. This specific explanation can be formulated more broadly, and I apply it to two other phonological cues to grammatical class in English—stress and vowel epenthesis. In general, phonological correlates to grammatical class could arise because (a) members of different grammatical categories vary in their distribution in sentences, (b) these distributional differences could have consistent phonological reflexes, and (c) listeners could encode these contextual effects as an acceptable variant of a word's context-free pronunciation. Thus, contextually driven phonological differences between grammatical classes could be ground into the lexicon as speakers produce those differences in new situations. At present, direct evidence exists only for the first 2 stages of this scenario, and it is unclear whether some contextual effects, such as the noun-verb duration difference, even have context-free parallels. However, as I describe later in an analysis of the English noun-verb stress difference, some indirect evidence is consistent with the third stage. In particular, certain types of words within a grammatical class might be more likely than others to appear in an environment that could affect pronunciation in a particular way. If listeners ascribe these contextual effects to a speaker's intended pronunciation, then, over the course of time, these subclasses of words should be more likely than others to have the contextual pronunciation accepted as standard.

Kelly (1988b, 1989) and Kelly and Bock (1988) have argued that the English noun-verb stress difference was at least partly caused by a general preference for rhythmic alternation in speech (see Selkirk, 1984, for a summary of the linguistic evidence for this preference) coupled with the fact that verbs are more likely than nouns to occur in contexts that bias them toward second-syllable stress. The primary context that has been implicated in this process concerns the types of inflections appended to nouns and verbs. More specifically, verbs are more likely than nouns to receive inflections that take a syllabic form, such as *-ing*. Because such syllabic inflections are weakly stressed, they would create a strong-weak-weak rhythmic pattern when added onto words with first-syllable stress (e.g., *promising*). This pattern violates the rhythmic alternation preference, and so the stem might be pressured to shift primary stress to the second syllable. Such a shift would create a weak-strong-weak rhythmic pattern and so preserve alternation. Because verbs are more likely than nouns to receive syllabic inflections, they would receive greater pressure to develop or maintain second-syllable stress.

Although consistent with the noun-verb stress difference, this account is clearly ad hoc. However, the explanation becomes more powerful because it predicts the existence of certain subpatterns in the English stress system. In particular, certain nouns and verbs might be more likely than others to receive syllabic inflections. One might therefore expect these subclasses of nouns and verbs to be more likely than others to have second-syllable stress. For example, the only verbs that receive a syllabic form of *-ed* are those that end in /d/ or /t/. Text analyses of spoken English in fact revealed that such verbs were over 6 times more likely than other verb classes to receive syllabic inflections. Furthermore, this difference was due completely to the role of past tense *-ed*. Based on this pattern, one would predict that the noun-verb stress difference would be particularly strong for noun-verb homographs ending in /d/ or /t/. Analyses of the English lexicon strongly confirmed this prediction, as 34% of a sample of noun-verb pairs ending in /d/ or /t/ had the standard contrasting stress patterns (e.g., *record*, *compound*, *permit*, *contest*), whereas only 5% of all other noun-verb pairs had the standard stress contrast (e.g., *recall*). As another example, consider the types of nouns that would receive syllabic versions of inflections for plural and possessive. All such nouns end in sibilant phonemes (e.g., *garages*), and so one would predict that nouns ending in sibilants would be more likely than other nouns to have second-syllable stress, a prediction that was also confirmed in analyses of the English lexicon. Finally, analyses of English speech revealed that verbs ending in /d/ or /t/ were most likely to receive syllabic inflections, followed by verbs ending in sibilants, and then all remaining verbs. As would be predicted, the same ranking was found when verbs from these different classes were categorized as having second-syllable stress listed in their dictionary entries (see Kelly, 1988b, for details).

Of course, these various textual analyses still assume that the contexts in question can affect stress patterns in the predicted ways. A variety of experiments using different inflectional contexts appended to both pseudowords and real English words have demonstrated that syllabic inflections can push stress assignments toward the second syllable of disyllabic words. One

experiment, for example, used disyllabic words that had optional stress assignments listed in a recent dictionary (e.g., *increase*, *rebound*). Given the optional status of stress with these words, inflectional contexts might be relatively potent in influencing stress assignments in a brief experiment. The target words ended in either sibilant phonemes like /s/ or the dental phonemes /d/ and /t/, and they acted as verbs in sentences with two different inflectional contexts. In one context, the verbs were marked with past tense *-ed*, whereas in the other context they were marked with third-person present singular *-(e)s*. For verbs ending in /d/ or /t/, past tense adds an extra syllable, whereas third-person present singular does not. Thus, for these words, higher levels of second-syllable stress are predicted for the past tense inflection. The exact opposite situation occurs with verbs ending in sibilants, as they receive an extra syllable when marked with third-person present singular but not past tense. Hence, higher levels of second-syllable stress should be found when these sibilant-ending words are marked with third-person present singular. Both of these predictions have been confirmed (Kelly, 1989).

In summary, nouns and verbs receive different types of inflections because of their different syntactic roles. These inflectional differences, however, have consistent phonological consequences that pressure the phonological structure of nouns and verbs in different ways and slowly grind stress differences into the two classes. A similar account has been proposed for the fact that the *-ed* on words like *ragged* is pronounced syllabically when the words are used as adjectives, but nonsyllabically when they are used as verbs (Minkova, 1985). In particular, text analyses of English revealed that adjectives are more likely than verbs to be followed by a stressed syllable. The primary reason for this difference is that adjectives often occur preminally, and, because English nouns are overwhelmingly either strongly stressed monosyllables or polysyllabic with stress on the first syllable, adjectives will be followed relatively often by a stressed syllable. This situation would violate the rhythmic alternation preference if the prenominal adjective is monosyllabic because this grammatical class is also associated with high levels of stress. One way to avoid a stress clash in phrases like *a ragged shirt* would be to pronounce the *-ed*. Because this suffix is weakly stressed, a strong-weak-strong pattern would be created, and the rhythmic alternation preference would be preserved. At present, no experiments have been conducted to determine if adjectives like *ragged* are more likely to be pronounced disyllabically when they are followed by a stressed syllable than when they are followed by an unstressed syllable.

One final, concrete example of the language change processes described in this section is provided by a clinical case study. Gandour, Marshall, and Windsor (1989) described a person with a speech production deficit who developed compensatory strategies that transformed English from a subject-verb-object language to subject-object-verb language. The speech production locus of the person's disability was documented by normal speech comprehension and syntactic structures in writing. However, the patient had difficulty in grouping syntactic phrases into phonologically coherent units. To compensate for this handicap, the patient took advantage of his partial ability to create phonological groups consisting of a stressed syllable

followed by a falling intonation on subsequent relatively unstressed syllables. Phonologically coherent verb phrases were therefore constructed by moving the verb from initial to final position and hence after the direct object. Gandour et al. attributed this behavior to the relative unstressed status of verbs compared with nouns. The patient's strategy thus created phonological groups that began with the stressed noun and concluded with less stressed material, including the verb. In this case, then, standard distributional differences between nouns and verbs created a phonological pattern that proved difficult for the patient to reproduce. Rather than alter the sound patterns of the language, as in the case of the noun-verb stress difference described above, the patient changed the basic word order of English. Perhaps his general pronunciation difficulties led to this syntactic solution rather than a phonological solution.

### Implications and Limitations

Thus far, this article has argued that phonology might provide information for determining the grammatical categories of words, and hence could assist in the initial assignment of words to the appropriate class as well as the rapid, ongoing classifications that must occur for successful comprehension. This information could therefore supplement syntactic and semantic cues to grammatical class. At this point, I discuss the potential implications of these phenomena for various issues in language processing in more detail. In the course of this discussion, possible limitations and unanswered questions are also considered.

### Representation

In pregenerative linguistics, stochastic approaches to language structure were common and influential (e.g., Harris, 1951). Since the rise of generative grammar, however, the architectures of syntax, morphology, and phonology have generally been represented in terms of rules (e.g., textbooks such as Matthews, 1974; Radford, 1988). In addition, many accounts of linguistic knowledge attribute to speakers rule-based representations that form the foundation of language capability and that manifest themselves in behaviors such as "well-formedness" judgments of syntactic, morphological, and phonological structures. For example, when assigning past tense to a verb, speakers could conceivably access a morphological rule that involves a past tense affix whose exact form (/d/, /t/, or /əd/) is determined by a phonological rule. Exceptions to the rule (e.g., *went* as the past form of *go*) could then be stored in a general associative memory, perhaps organized around a set of prototypes to account for subpatterns within the violations of the general past tense rule (Bybee & Slobin, 1982; Pinker & Prince, 1988).

These rule-based models seem less appropriate for linguistic patterns that are extremely probabilistic, so that many exceptions to typical patterns exist. The correlations between phonology and grammatical class discussed in this article appear to be of this sort. For example, though English verbs tend to contain fewer syllables than English nouns, many violations to the pattern exist, such as the monosyllabic nouns *car* and *cat* and the polysyllabic verbs *pacify* and *hibernate*. The use of rule

systems as cognitive models of how such probabilistic relations are represented and accessed could be cumbersome and might distort their fundamentally stochastic nature. Indeed, not only is the input to the cognitive system (i.e., correlations within the lexicon of a language) probabilistic in nature, but so is the output from the cognitive system. For example, Cassidy and Kelly (1991) found that English speakers used monosyllabic nonsense words more often as verbs than they used polysyllabic nonsense words, whereas the reverse was true of nouns. However, this behavior was quite probabilistic, with subjects often using polysyllabic words as verbs and monosyllabic words as nouns. Although systematic, the subjects' behavior in that experiment and others does not appear rulelike.

In contrast to rule-based representations, spreading activation or connectionist models might capture knowledge of phonology-grammatical class correlations rather well. Indeed, it is this type of probabilistic information that such models are particularly well-suited for, because they are basically large-scale correlation detectors. Furthermore, these systems can weigh a variety of information sources simultaneously and thus make combined use of individually weak phonological cues to grammatical class. In contrast to connectionist models of more rulelike linguistic structures, such as English past tense morphology (Rumelhart & McClelland, 1986; for critique see Pinker & Prince, 1988), the phenomena reported in this article might offer a more firm basis for connectionist applications to the linguistic domain.

One example of such an application is MacWhinney, Leinbach, Taraban, and McDonald's (1989) connectionist model of gender classification for German nouns. Their initial model consisted of a set of input units that encoded German nouns in terms of a variety of phonological, morphological, and semantic cues to German gender. Other input units encoded the case for each noun on a given trial, such as nominative or accusative. A set of intermediate units then detected correlations among the various cues to gender. The model's task was to weigh the gender and case information and then select for output an appropriate German definite article for the noun, such as *der*, *die*, or *das*. The model succeeded in learning the proper gender for almost all of the nouns in the training set, with difficulties encountered on only a couple of items. More important, the model showed generalization abilities, as it selected the correct definite article for novel items at accuracy levels that were significantly above chance.

One problem with this model, however, is that MacWhinney et al. (1989) basically told the system to what phonological features it should attend. For example, German nouns ending in a fricative followed by /t/ tend to be masculine, and the connectionist model explicitly encoded whether or not words ended in this sequence. Of course, this arrangement is not natural because children are not explicitly instructed to pay attention to words ending in certain patterns because they might be correlated with gender. However, in another model designed to address this issue, MacWhinney et al. did not incorporate such detailed information in the initial representation of a word. Instead, each word was represented in terms of basic phonological features such as voicing and place of articulation, and the model would have to learn for itself which features and combinations of features mattered. This model significantly outper-

formed the first one, indicating that correlations could be detected from the raw phonological input. Furthermore, the greater success of this model might indicate the existence of other, previously unknown phonological correlates to German gender, which the model learned and used to assist gender classification. If so, then such connectionist systems might be used not only to model the learning of previously documented cues to grammatical class, but also to identify cues that were not explicitly known to linguists or psycholinguists.

The potential success of connectionist models might lead to proposals that grammatical categories should be defined probabilistically rather than discretely through rule-based criteria. In such a view, the categories of nounhood and verbhood would be organized around prototypes that are formed from semantic, morphological, and phonological predictors of grammatical class (see Bates & MacWhinney, 1982, for a detailed proposal along these lines). Hence, the noun and verb classes would grade into one another, with no sharp boundary distinguishing them. Nonetheless, certain aspects of a rule-based approach to grammatical class might be preserved. Consider, for example, the sentence *The gazelle grazed on the African plain*. The subject noun of this sentence, *gazelle*, has a stress pattern that is not typical of the English noun class. Although the atypical stress pattern of *gazelle* might cause listeners some delay in making the correct grammatical category assignment, it would nevertheless be classified ultimately as a noun. Furthermore, such a classification would be necessary if the correct syntactic structure, and hence interpretation, of the sentence were to be attained. Thus, while phonological patterns (and semantic patterns for that matter) might be important identification heuristics for grammatical category assignments, they might not be the identification criterion. That attribute would ultimately belong to the domain of syntax. Hence, a distinction would be drawn between the information used to make initial inferences about the grammatical classification of a word and the ultimate manner in which that word is represented in a grammatical class.

Objections to a superfluous distinction between identification heuristics and criteria might be made, but it should be pointed out that reference to such a distinction would not be idiosyncratic to the linguistic domain. For example, classification theories for common categories like birds and fruit have often resorted to the same distinction (e.g., Rey, 1983; E. E. Smith, Shoben, & Rips, 1974). Thus, a variety of evidence suggests that probabilistic cues associated with certain categories affect learning rates and classification decisions (e.g., Rosch & Mervis, 1975), and yet many theorists have still denied that such probabilistic patterns necessarily define a category. Thus, Rey (1983) wrote

For all their "probabilistic" conclusions regarding the concept bird, I doubt very much that [prototypicality theorists] want to claim that a penguin is a bird only to a relatively small degree, *much less that anyone actually thinks so*. I strongly suspect that most people consider penguins to be . . . birds to degree 1—despite their slight hesitation in judging them to be so. (p. 248)

An almost identical statement could be made regarding *gazelle* in the sentence discussed earlier. Such opinions seem all the more reasonable given the existence of certain categories

that have uncontroversial definitions, such as odd and even number. Yet even here classification decisions can be affected by features that are typical of the class but not necessary (Armstrong, Gleitman, & Gleitman, 1983). Thus, like morphological and behavioral correlates of the bird class, phonological correlates to grammatical category might exist, be learned, and facilitate language processing, but they would not be the criteria that define those classes. In the final analysis, syntactic considerations would hold sway. For the present, however, this important issue remains open.

### *Language Acquisition*

In the introduction, I noted that discussions of grammatical category assignment in the language acquisition literature have focused on syntax and semantics to the virtual exclusion of phonology. Syntactic or distributional information for grammatical class, though language specific, is attractive because it can be described as a set of rules. Although probabilistic, semantic information is attractive because of its universality, and hence its possible basis as an innate link between conceptual and formal categories. Thus, children would not have to learn these semantic correlates but instead would be prepared to associate different semantic features with different syntactic categories. Because of their inconsistency both within and across languages, phonological cues to grammatical class would presumably be less learnable and important in assigning words to grammatical categories. A number of responses could be made to this criticism.

First, one could argue that the language specificity of a phonological cue is irrelevant so long as children can learn the cue quickly. Some evidence does in fact indicate that very young infants are sensitive to at least gross aspects of the phonological structure of their language. Thus, Mehler et al. (1988) showed that 4-day-old French children could discriminate their language from a foreign one, although they could not distinguish between two foreign languages. Furthermore, this effect was not due to the general beauty or salience of the French language. Two-month-old American children (the earliest age tested) could discriminate English from a foreign language but could not discriminate between two foreign languages, one of which was French. Thus, through early prenatal experience, postnatal experience, or both, children can learn some phonological cues characteristic of their language. The possibility that children learn the phonological cues that characterize nouns and verbs in their language very rapidly, therefore, cannot be ruled out. Indeed, given the remarkable sophistication of infant perception that has been demonstrated repeatedly over the past 30 years (see Gibson & Spelke, 1983, for review), it would not be advisable to bet against children in this area. In fact, in the specific domain of speech perception, evidence indicates that infants can perceive phonemic distinctions (see Gleitman et al., 1988, and Jusczyk, 1986, for reviews), stress patterns (Spring & Dale, 1977), phonological correlates to clause boundaries (Hirsch-Pasek et al., 1987), and idiosyncratic patterns that distinguish mother's speech from an unfamiliar adult female's speech (Mehler, Bertonicini, Barriere, & Jassik-Gerschenfeld, 1978). The current track record, therefore, holds out promise that phonological information for grammatical class could be

detected and learned by young children. In fact, some evidence suggests that children might be even more sensitive than adults to phonological information, such as prosody, for grammatical structures (Read & Schreiber, 1982). Such sensitivity may be important because closed-class items provide many of the distributional cues to grammatical class. However, these items are weakly stressed, and unstressed syllables create well-documented difficulties for young children (Gleitman et al., 1988). Thus, the syntactic material that could provide sufficient information for grammatical category assignments is imperfectly encoded by children. Attention to gross phonological patterns (e.g., stress or syllable number) and the internal phonological structure of stressed syllables might compensate for imperfect registration of syntactic material, much like a word context helps observers to identify an imperfectly registered letter.

Second, the development of learning models that use probabilistic information for grammatical class could render plausibility to the approach. As described in the prior section, MacWhinney et al.'s (1989) connectionist model of gender assignment in German was successful in learning the phonological features and combinations of features that were predictive of nominal gender. In addition, the model duplicated a number of patterns observed in the acquisition of the German gender system, such as the child's use of word final *-e* as a cue to feminine gender. Finally, the model could serve as a useful heuristic for predicting the existence of currently undocumented patterns in language acquisition. In particular, the MacWhinney et al. model exhibited some behaviors that had not been noticed before in the acquisition of German. If the model does in fact capture the details of German gender acquisition, then these behaviors should be observed in children. Of course, certain aspects of the model could be seen as solving some problems by assuming solutions to others. For example, although their model is given the task of learning phonological predictors of German gender classes, MacWhinney et al. provided the model with the proper output categories from the start. It remains to be seen whether a connectionist model can simultaneously induce the gender classes as well as their predictors from an input representation of speech.

Third, there are numerous tasks that must be solved in language acquisition and a variety of systematic phenomena associated with these tasks that need to be explained. Phonological correlates to grammatical class may be relatively unimportant in some but significant in others. Hence skepticism about one function might not apply to other issues in acquisition. For example, children must not only make inferences about the grammatical class of a novel word in someone else's speech, but also remember the correct assignment for proper use in their own speech. Phonological information might therefore be ignored in making initial grammatical category assignments, but exploited in establishing a word's grammatical class in memory (see the discussion of language production later).

As a final example of a developmental phenomenon that might be partly due to phonological differences between grammatical categories, consider the rate at which different word classes are acquired by children. Gentner (1982) has provided extensive documentation that nouns tend to be acquired before verbs. Furthermore, Gentner summarizes evidence that this pattern appears not only in English, but also in other languages.

some of which are typologically quite distinct from English. Gentner examines and eliminates a number of possible reasons for this noun-verb difference, such as word frequency, and instead offers a semantic account. In particular, noun meanings tend to be more tightly associated with immediate concrete perception, and the nature of their denotations is more consistent across languages. Verb meanings, on the other hand, have greater variability across languages and less systematicity within languages (see also Huttenlocher & Lui, 1979).

While I do not dispute semantic contributions to this acquisition pattern, I would like to suggest a role of phonological structure. As discussed earlier, nouns tend to be longer in duration than verbs in typical English sentences. This difference could be due to the fact that nouns are more likely than verbs to occur phrase and clause finally and hence, to receive lengthening concomitant with those syntactic boundaries (Sorenson et al., 1978). Given that "motherese" generally exaggerates prosodic patterns found in adult speech (Fernald & Simon, 1984), these lengthening differences between nouns and verbs would be increased. Nouns, therefore, would be more acoustically salient than verbs and hence, more easily detected and learned. If this were true, some predictions would follow.

First, children might produce verbs less accurately than nouns. This prediction, which has supportive evidence (see Schwartz, 1988, for summary), follows from the possibility that the correct structure of verbs would be more difficult for children to detect in parental and/or sibling speech. Second, certain verbs might tend to occur relatively often phrase and clause finally and would be more acoustically marked than other verbs. One would expect that these verbs would be acquired earlier than verbs that do not occur often at phrase and clause boundaries. Third, children learning languages in which verbs tend to occur clause finally, should, in the strongest prediction, acquire verbs before nouns. In her cross-linguistic analyses, Gentner did include some languages, such as Japanese, that place the verbs at the ends of clauses in their basic word order. However, she did not observe any significant correlation between word order patterns and the tendency for verb acquisition to lag behind noun acquisition. Nonetheless, it should be pointed out that the sample sizes for each language were relatively small, ranging from 2 to 4 children per language. Furthermore, 14 of the 16 children examined were under 2 years of age, and hence, before the period of rapid verb acquisition. Perhaps durational or other factors of phonological salience have a greater impact in this period of vocabulary growth and hence lead to predictions about which nouns and verbs will be acquired earliest. However, given existing evidence that phonological prominence has a significant impact on language acquisition (for major reviews and discussion, see Gleitman & Wanner, 1982; Gleitman et al., 1988), it would be surprising if differences in the acoustic salience of nouns and verbs did not affect acquisition patterns for these two classes.

### Language Production

During language production, speakers must successfully access appropriate words from memory at a rapid rate. As Levelt (1989) describes this achievement,

A normal educated adult speaker of English has an active vocabulary . . . of about 30,000 words. A speaker makes the right choice from among these 30,000 or so alternatives not just once but, in fluent speech, continuously two to five times per second. . . . Still, the error rate is very low." (p. 199)

One component to this feat is the retrieval of words from the correct grammatical class. Thus, if a speaker has said "The boy will . . .," the next word should not be a noun, but a verb would be acceptable. One source of information that might be used to restrict access to the appropriate form class is syntactic. Thus, as a sentence frame is constructed, words could be targeted for retrieval if they fit in specific syntactic slots. However, as noted by Levelt, the speed and accuracy with which speakers carry out lexical retrieval is impressive. Perhaps this accuracy is achieved in part by relying on phonological correlates to grammatical class in addition to syntactic specifications. Hence a search for a verb could activate items with the typical phonological characteristics of verbs and inhibit the activation of items that do not share those phonological features and so are unlikely to be verbs. Such a process would not only be consistent with the high accuracy of lexical retrieval, but also might explain systematic patterns in retrieval errors. In particular, when speakers inadvertently say one word in place of another, the target and error almost invariably are members of the same grammatical class. Thus, even in failure, speakers still succeed in selecting a word of the proper grammatical class. This partial success might, of course, reflect syntactic constraints on lexical selection. However, strong phonological similarities between the target and error indicate that phonological information might help to restrict memory search to words from the correct grammatical class. Thus, targets and errors in word substitutions are not only drawn from the same grammatical class, but also have the same number of syllables and stress pattern (Fay & Cutler, 1977). In tip-of-the-tongue states as well, the intended word and the intruders called to mind in its stead are also generally identical along the dimensions of grammatical class, syllable number, and stress pattern (Brown & McNeill, 1966). Such constraints have been used to argue that the mental lexicon is organized according to these same dimensions (Fay & Cutler, 1977). However, such conclusions presuppose that these various dimensions are orthogonal. As the evidence discussed in this article demonstrates, however, they are not. Thus, stress pattern and syllable number in English are correlated with grammatical category. The grammatical category constraint in speech errors may fall out of the phonological constraints and partly account for the near-perfect success speakers have in retrieving words of the proper grammatical class from memory.

### Language Comprehension

Although syntactic information could provide sufficient evidence concerning the grammatical classes of words in a sentence, that information might not be immediately available to a listener. For example, the sequence *The town permits . . .* is ambiguous in either a reading in which *town* is a noun and *permits* is a verb or a reading in which *town* is an adjective and *permits* is a noun. What language comprehension procedures are used to resolve such ambiguities? Frazier and Rayner (1987) provide evidence for a delay strategy in which grammatical cate-

gory assignments are suspended until disambiguating information is encountered. In sequences like *These town permits . . .* or *This town permits . . .*, the initial article provides this disambiguating information, and further sentence material is not needed. Eye movement data during reading of such structures indicate that subjects do indeed commit immediately to a noun-verb interpretation of *This town permits . . .* and delay such an early commitment in *The town permits . . .* until subsequent material is processed.

Frazier and Rayner (1987) point out that delays in grammatical category assignments could increase processing demands in sentence comprehension. However, such delays may be relatively rare in speech comprehension because various acoustic cues might provide immediate information about grammatical category assignments. For example, if *permits* in *The town permits . . .* is pronounced with first-syllable stress, an article-adjective-noun reading is indicated, whereas if *permits* is pronounced with second-syllable stress, an article-noun-verb reading is indicated. By using written materials that inherently give priority to syntactic information over truly absent auditory information, investigators may underestimate the amount of grammatical category information normally available in speech and overestimate the extent to which the delay strategy in parsing must be implemented. In reading, the delay strategy may be less troublesome because the reader can easily turn back and reparse a sentence. Delay strategies would interfere more with speech processing where these reparsing options are not available. In addition to analyzing various parsing strategies, therefore, it may be advantageous to investigate the types of syntactic disambiguation cues available in the acoustic structure of speech. The research described in this article and in others (e.g., Cooper et al., 1978) suggests that a good deal of acoustic information exists to assist sentence parsing and that the focus on written material in the study of parsing may underestimate the availability and use of such information.

### *Language Change*

Some of the phonological correlates to grammatical class discussed in this article, such as stress and syllable number in English, have been present for centuries. These correlations could have been implicitly known by past as well as present speakers. Such knowledge might have provided local assistance in language processing in the past and, more globally, might affect the evolution of a language as a whole. Earlier, for example, I discussed a very common lexical innovation in English in which words that originate in one grammatical class could develop uses in others (see Clark & Clark, 1979, for further discussion). An experiment using current English speakers showed that the likelihood of such grammatical extensions depends partly on phonological information. In particular, subjects were more likely to use disyllabic nouns as verbs if they had the standard verb stress pattern and to use verbs as nouns if they had the standard noun stress pattern. The rationale of this experiment can be generalized to the history of English with the same predictions. An analysis of English nouns and verbs (Kelly, 1988a), did indeed find that, over the course of English history, nouns with second-syllable stress have been more likely than nouns with first-syllable stress to develop verb uses,

whereas the opposite pattern was found with extensions from verb to noun (Kelly, 1988a).

### Conclusions

A variety of optical information could be used to perceive a three-dimensional environment, including motion parallax, binocular disparity, and height in the projection plane. Furthermore, human beings are sensitive to a large range of such cues, and incremental removal of cues leads to incremental degradations in three-dimensional perception (e.g., Bruno & Cutting, 1988). In a similar manner, the grammatical class of a word could be determined by simultaneously using various types of syntactic, semantic, and phonological information. Given that such information exists, there is no a priori reason to expect one or more of these domains to be excluded in favor of the others. However, investigations of how adults and children determine the grammatical category of a word have placed overwhelming emphasis on semantic and syntactic information, to the exclusion of phonology. This practice would be justified if phonology provided little or no accuracy in predicting grammatical class. However, this justification is groundless, as this article has documented that phonological cues to grammatical class are plentiful and, in some cases, individually strong. Phonology could, in turn, be justifiably neglected because human beings are not sensitive to the information on grammatical category provided by this domain. Once again, however, this hypothesis is also false, as many experiments using different subject groups, phonological variables, and experimental techniques have shown that human beings have revealed at least some correlations between phonology and grammatical class. Indeed, human beings have been shown to be sensitive to every phonology-grammatical class correlation that has been investigated. One could object further and argue that sensitivity does not entail regular use of phonological variables in learning or processing grammatical category information. While this point is true at the moment, it must be emphasized that the same state of affairs exists for other sources of information on grammatical class. Thus, studies such as Brown's (1957) that demonstrate child knowledge of semantic predictors of grammatical category do not document that this knowledge is regularly exploited outside of a laboratory setting. Furthermore, knowledge of grammatical category-phonology correlations can have an impact on language use outside of the laboratory. Thus, knowledge of the English noun-verb stress asymmetry has affected the likelihood that certain nouns will develop verb uses in English history and vice versa (Kelly, 1988a).

In summary, the relative emphasis placed on semantics, syntax, and phonology as information sources for grammatical category reflect current research "bets" as to the true relative importance of these domains. However, at present, researchers do not even have approximate measures of what the odds are to support these existing betting practices. Indeed, unless phonology plays virtually no role in grammatical category assignment, this domain is certainly underweighted. A variety of explanations can be offered for the neglect of phonology, ranging from the tradition of describing language as strictly rule-governed rather than partly stochastic to a tendency to see language as a cognitive faculty (and hence heavily semantics

driven) rather than as a perceptual system. In any case, current research on the grammatical category assignment problem is heavily skewed away from phonology, and this bias may reflect theoretical and empirical assumptions that do not have a "sound" basis in fact.

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