

Phonological and Form Class Relations in the Lexicon

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Two experiments were conducted to examine the structure of the mental lexicon. A lexical search of American English, using the Brown corpus (Francis and Kucera, 1982), revealed a skewed, frequency-dependent distribution in which the syntactic classes of noun and verb are distinguished in terms of the phonological classification of their vowels. Among high-frequency words, nouns are more likely to have back vowels (57%) rather than front vowels (43%) and verbs more likely to have front vowels (62%) than back vowels (38%). This distribution, however, does not hold for low-frequency nouns and verbs in the language. Noun and verb stimuli containing front and back vowels were examined in both an auditory noun/verb categorization task and an auditory lexical decision task. In general, the phonotactic composition of nouns and verbs in the lexicon was shown to have perceptual consequences. Listeners seem to be differentially sensitive to incoming sound patterns on the basis of distributional properties of the lexicon.

A fundamental issue of interest in word recognition studies is the structural relations among lexical items. Although many experiments have emphasized the semantic or associative relationship among words, few studies have examined the phonological structure of the lexicon or the way in which this factor interacts with other lexical variables. The present study will investigate systematic phonological relations in the lexicon

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using both a lexical search procedure to document their distribution in the language and an experimental approach to test whether these lexical patterns affect word recognition processes.

Statistical properties involving the phonological structure of the English lexicon have been investigated by Shipman and Zue (1982) and Huttenlocher and Zue (1984). They found that there are strong structural constraints at the phonological level in language. For example, simply specifying the consonant-vowel pattern of a given input word will reduce the number of potential word candidates in a 20,000-word vocabulary, on average, to only 20 possible lexical items (Shipman and Zue, 1982). These results indicate that partial specification at the segmental level dramatically reduces the number of possible word candidates since there are powerful constraints on the sound patterns found in the lexicon.

In addition to systematic phonological structure in the lexicon, important phonological differences within the lexicon have also been documented. The early research of Landauer and Streeter (1973) and the more recent verification of their claims by Pisoni, Nusbaum, Luce, and Slowiaczek (1985) and Pisoni and Luce (1986) have shown that high-frequency lexical items seem to be phonologically distinct from low-frequency lexical items. Invoking the notion of a similarity neighborhood (word neighbors differing in only one phoneme), Landauer and Streeter (1973) found both that high-frequency words tend to occur in dense neighborhoods and that the neighbors of high-frequency words tend to be high-frequency words. Thus, there appear to be fundamental structural differences in the distribution of high- and low-frequency words. Landauer and Streeter (1973) further examined the phonemic constituents of high- and low-frequency words and concluded that similarity neighborhood differences seem to be the result of differences in the distribution of phonemes in these items. The phonemes that tend to occur very often in high-frequency words are not the same phonemes that make up low-frequency words.

More recently, Luce (1986) has shown that the nature of the similarity neighborhood, as well as the frequency of the stimulus item per se, affects reaction times in word recognition studies. The density of the neighborhood and the frequency of those neighbors, in addition to stimulus word frequency, are also very good predictors of the speed and accuracy of auditory word recognition in a variety of tasks (word identification in noise, lexical decision, pronunciation). The number and nature of words in the similarity neighborhood—in other words, the phonological structure of the lexicon—have important consequences for models of word recognition.

In linguistic theory, the phonological structural relations in the lexicon and their interactions with other lexical variables have also been considered. Specifically, the correspondence between the set of meaningful forms of a language and the various phonemes which make up these forms falls within the study of *sound symbolism*, a term originally coined by de Saussure. However, de Saussure (1959) claimed that the connection between the signifier (the sound-image) and the signified (the concept) is arbitrary and, in general, many linguists have tended to adopt that doctrine advocated by de Saussure. However, there is far from unanimous agreement with this principle of arbitrariness. A variety of scholars from different disciplines (e.g., Humboldt, Peirce, Bloomfield, Bolinger, and Jakobson) have disputed the claim that the signified is not bound to the sequence of phonemes that serve as its signifier, citing a variety of correspondences of sound and meaning in the languages of the world (see Jakobson, 1965, 1978).

In recent years, two widespread and consistent cases of sound symbolism have been discovered in the work on language universals (see Greenberg, 1978). First, Ultan (1978) found evidence for distance symbolism.³ In an analysis of 136 languages, Ultan found that 33.1% of the sample exhibited distance symbolism in their demonstrative system. More importantly, those languages that overtly symbolized distance relationships predominantly used front or front-high vowels to represent proximity to the speaker.

Second, Ultan found universal correspondences for size symbolism in language. Some languages overtly mark words expressing diminution by changing the phonological features of the vowel sound in the root. Ultan found that 27.3% of the 136 languages he sampled had diminutive marking. In almost 90% of these languages, the diminutive was symbolized by front-high vowels. The widespread distribution of these consistently recurring patterns of sound symbolism suggests that the relation between sound and meaning in language may not be completely arbitrary.

Taking into account the systematic phonological structure of the lexicon that has been documented and shown to affect word recognition and using the universal semantic-sound correspondences as a model, a different type of phonological structure in the lexicon is suggested here.

³ The notion of distance symbolism must be considered within the broader framework of deixis. *Deixis* refers to those features of the language which reflect the spatio-temporal coordinates of the relative situation of the utterance. Distinctions are made between things that are near in space and/or time vs. things that are far in space and/or time.

Correspondences between phonological content and two clearly delineated and linguistically salient categories of syntactic class are analyzed. Specifically, the syntactic classes of *noun* and *verb* are compared in terms of the phonological classification of their vowels. The present paper will first document the correspondences between specified phonological features of the vowel and different syntactic categories and then test whether this lexical pattern affects word recognition.

Both the syntactic class categorization and the phonological classification of the vowels are basic distinctions in language. No language fails to distinguish the syntactic categories of noun and verb, suggesting the universality of this distinction in the languages of the world (Hockett, 1968; Sapir, 1944). Moreover, the classification of front vowels as distinct from back vowels is acoustically and articulatorily as well as perceptually salient (Ladefoged, 1975; Pickett, 1980). An explanation in terms of formant frequencies, the resonant frequencies of the vocal tract, suggests that front vowels are characterized by a relatively high second formant frequency (F2) due to a tongue constriction close to the front of the oral tract, whereas back vowels are characterized by a relatively low F2 due to a tongue constriction close to the back of the oral tract. Moreover, the perception of front and back vowels has indeed been shown to be dependent on the frequency location of F2 (Carlson, Fant, & Grantsröm, 1975).

A lexical search was undertaken to carefully examine the relationship between syntactic class membership and phonological vowel classification. Using the Brown corpus (Francis and Kucera, 1982), the first 1000 noun and verb lemmata in the rank list were classified according to the phonological category of their stressed vowel (front vowel [i, I, e, ε, æ] vs. back vowel [ɔ, a, ʌ, ɔ, o, u, u, aI, au, ɔI]).⁴

The phonological analysis of the nouns and verbs in the Brown corpus revealed a systematic, skewed distribution. In general, high-frequency stimuli (i.e., greater than 200 per million) pattern differently than low-frequency stimuli (i.e., less than 200 per million). Moreover, the stimuli within each of the two frequency-based groups show a consistent

⁴ In the present analysis, the base form of each word is used. Diphthongs are classified on the basis of the more prominent first vowel sound (Ladefoged, 1975) and multisyllabic words are analyzed for the vowel in their stressed syllable. A previous analysis (Sereno, in press), using both the Lorge (1949) frequency word list and the Francis and Kucera (1982) list, had shown that the exclusion of all possible controversial cases (e.g., multisyllabic words, words containing diphthongs, and words that change the categorization of the stressed vowel such as strong verbs with alternative forms) did not affect the categorization results.

pattern.⁵ For present purposes, only two sets of 200 stimuli (a high-frequency set and a low-frequency set) are presented and analyzed in terms of vowel quality. For the high-frequency set, the first 200 nouns and verbs in the rank list of the Brown corpus were analyzed. These words have frequencies ranging from approximately 3000 per million to 250 per million. In these high-frequency words, nouns are more likely to have back vowels rather than front vowels in their stressed syllables while high-frequency verbs are more likely to have front vowels than back vowels. Specifically, only 43% of nouns have front vowels while 57% have back vowels. This pattern is reversed for the verbs, with 62% of the verbs having front vowels and only 38% having back vowels. A chi-square test for these high-frequency words showed that there is indeed a significant relationship between the syntactic category of the word and the front/back quality of the stressed vowel of the word ($\chi^2 = 6.23, p < .02$).

A similar distribution, however, is not maintained for low-frequency nouns and verbs. For the low-frequency set, the first 200 nouns and verbs in the rank list having a frequency less than 50 per million were analyzed. These words have frequencies ranging from 50 per million to approximately 30 per million. In these low-frequency words, the proportion of front and back vowels for both nouns and verbs is virtually identical. For low-frequency words, 54% of nouns have front vowels and 46% have back vowels; 49% of verbs have front vowels and 51% have back vowels. A chi-square test for these low-frequency words showed that there was no significant relationship between the syntactic category of the word and the vowel quality of the stressed vowel ($\chi^2 = 0.47, p > .50, n.s.$). Thus, for high-frequency words, there is a significantly greater number of nouns with back vowels and verbs with front vowels, but this pattern does not hold for low frequency nouns and verbs in English.

To further investigate these syntactic class and vowel quality correspondences, two experiments were conducted to determine whether this relationship is effective in the processing of language. Both experiments were presented in the auditory modality. The first experiment consisted of a noun/verb categorization task while the second experiment was a lexical decision task. If it is the case that a systematic relationship obtains between syntactic class and phonological features of the stressed vowel,

⁵ A complete analysis of the Brown University corpus (Francis and Kucera, 1982) in terms of form class membership and vowel classification is presented in Sereno (in press).

it may be expected that nouns with back vowels and verbs with front vowels will be processed faster due to the listener's sensitivity to the distribution of nouns and verbs and front and back vowels. In addition, a comparison of the frequency of the stimuli can clarify whether such an effect is a distributional consequence of the language (response latency differences present only in high-frequency stimuli) or a general processing strategy (response latency differences present in both high- and low-frequency stimuli).

EXPERIMENT 1

The purpose of this experiment was to determine whether the interaction between the vowel category of a word and its form class would be observable in a word recognition task. In this experiment, a noun/verb categorization task was employed in which subjects were to decide whether an auditorily presented stimulus item was a noun or a verb. This task was used in an attempt to maximize, on the one hand, the acoustic-phonetic differences in vowel category by presenting stimuli in the auditory modality and, on the other hand, the contrast between nouns and verbs by using a noun/verb categorization paradigm.

Method

Subjects. Twenty students attending Brown University were paid to participate in the experiment. All were native speakers of American English and reported no history of speech or hearing disorders. No subject participated in more than one of the present experiments.

Stimuli. Sixty-four words (32 nouns and 32 verbs) were selected from the Brown corpus (see the appendix). Each of the noun stimuli is used at least 90% of the time as a noun and each of the verb stimuli is used at least 90% of the time as a verb. Each of the noun and verb groups was equally divided on the basis of vowel quality, with one-half of the stimuli having front vowels and the other half back vowels. Moreover, the stimuli were equally divided into high-frequency words (occurring more than 250 times per million) and low-frequency words (occurring between 50 and 30 times per million). Thus, for the nouns, there were eight high-frequency front-vowel nouns, eight low-frequency front-vowel nouns, eight high-frequency back-vowel nouns, and eight low-frequency back-vowel nouns. Likewise, for the verbs, there were eight high-frequency front-vowel verbs, eight low-frequency front-vowel verbs, eight

high-frequency back-vowel verbs, and eight low-frequency back-vowel verbs.

Within each list of nouns and verbs, all subgroups (front-vowel nouns, back-vowel nouns, front-vowel verbs, and back-vowel verbs) were matched for word frequency (Francis and Kucera, 1982). For the high-frequency stimuli, mean frequency of occurrence for front-vowel nouns, back-vowel nouns, front-vowel verbs, and back-vowel verbs was 452, 443, 442, and 437 per million, respectively, with standard deviations of 179, 164, 153, 133, respectively. Low-frequency words were similarly matched. Mean frequency of occurrence was 42, 41, 39, and 44 per million, respectively, with standard deviations of 5, 4, 10, and 6, respectively.

Only monosyllabic words were used, and all stimuli were matched for mean number of phonemes. All subgroups of stimuli were comparable in duration. For high-frequency stimuli, durations for front-vowel nouns, back-vowel nouns, front-vowel verbs, and back-vowel nouns were 644, 606, 644, and 614 ms, respectively, while for low-frequency stimuli mean durations were 621, 596, 648, and 606 ms, respectively.

Procedure. All subjects were tested in groups of one to three. For the noun/verb classification task, subjects were instructed to identify each stimulus either as a noun or a verb. They were told that the stimuli were all familiar English words and that, although some of the words could occur both as a noun and a verb, each stimulus was to be categorized on the basis of its more frequent usage. Subjects were to respond as quickly and accurately as possible to each stimulus item. Following instructions, subjects were given a set of eight practice items to introduce them to the procedure. These practice items were not used in the experiment.

The stimuli were first recorded by a male speaker on a Sony tape recorder in an anechoic chamber using a Bruel and Kjaer 4179/2660 microphone. The stimuli were then digitized on a microVAXII computer at a sampling rate of 20 kHz with a 9.0-kHz low-pass filter setting and 10-bit quantization. The stimuli were then transferred to an IBM AT personal computer and converted to 12-bit quantization for playout to the subjects. Subjects listened to the stimuli over Sony (MDR-2V) headphones at a comfortable listening level. All responses to the stimuli were made by pressing one of two clearly marked buttons on a response box placed in front of the subjects. Each trial was completed when subjects used the index finger of their preferred hand to press one of the two equidistantly placed response buttons labeled *noun* or *verb*. Position of the response buttons was counterbalanced across subjects.

