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Can semantic constraint reduce the role of word frequency during spoken-word recognition?

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There is increasing evidence that the properties of a spoken word such as its length or its phonotactic configuration interact with the preceding semantic context during word recognition: the more constraining the context, the less important the role of the word properties. The gating paradigm (Grosjean, 1980) was used to show that the impact of the frequency of occurrence of a word can also be reduced by the semantic context preceding that word. A 66-msec difference between the time it takes to isolate low- and high-frequency words in a low-constraint condition was reduced to a 4-msec difference in a high-constraint condition. The theoretical implications for this significant interaction are discussed briefly.

There appears to be increasing evidence that the properties of a word, such as its length in syllables, its frequency of occurrence in the language, and the frequency of occurrence of its first syllable, interact with the preceding context during spoken-word recognition: the more constraining the context, the less important the role of the various properties of the word. For instance, Jakimik (1979) found a significant interaction between the constraint of a carrier sentence and the frequency of occurrence of the first syllable of the following word: The difference between the time required to detect mispronunciations in words with frequently occurring first syllables (as in "inventor" and "convertible") and the time required for those with infrequently occurring first syllables (as in "spaghetti" and "vampire") was 113 msec when the preceding context was neutral but only 40 msec when the context was constraining. Grosjean (1980) found a significant interaction between context and the length of a word: As the context became more constraining, the length of the word played less of a role in the time it took to isolate the word. The difference between the isolation times for one- and three-syllable words was 118 msec in a no-context condition but only 57 msec in a long-context condition.

In the present paper, we turn to the relationship that exists between context and word frequency. A number of studies have examined this phenomenon (e.g., see Becker, 1979, Schuberth & Eimas, 1977, and Schuberth, Spoehr, & Lane, 1981), but almost all have involved the recognition of printed words. In addition, these studies have obtained contradictory results: Some show a statistical interaction between semantic constraint and word frequency, whereas others do not. Our aim here is not to explain this contradiction but rather to account for an earlier finding (Grosjean, 1980) pertaining to the relationship that exists between context and frequency in spoken-word recognition. In that study, Grosjean used two levels of word frequency and three levels of context and found no interaction between context and frequency, whereas he did find an interaction between context and another property of the word–its length. A possible explanation for this–taken in part from Becker (1979)–is that the highest level of context used was simply not constraining enough to allow it to reduce the role of word frequency in any significant manner. In order to verify this explanation, we ran a gating study very similar to that of Grosjean (1980) but made sure that the three context conditions that were used covered a full range of semantic constraint–from very low to very high constraint.

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METHOD

Subjects

Twenty-four undergraduate subjects, with no reported speech or hearing defects, served individually in sessions lasting 30 min.

Materials

Eleven noun pairs, matched for length (two syllables), stress pattern, and initial phoneme were chosen from the Kučera and Francis (1967) word-frequency list. One of the nouns in each set was of low frequency (count of 1), and the other was of high frequency (count of 40 or above). Each word was embedded in a three-phrase sentence, as in "In front of her pupils, and answering a question, the *teacher* started to smile." To determine the semantic constraint of the information preceding the stimulus word, each sentence was divided into three parts: the stimulus word preceded by the definite article ("the teacher");

the stimulus word preceded by one phrase ("answering a question, the teacher"); and the stimulus word preceded by two phrases ("In front of her pupils, and answering a question, the teacher"). These parts (66 in all) were randomized and then given to 10 judges, who were asked to rate the level of constraint of the context preceding the stimulus word by marking a rating scale (a straight line 90 mm long) labeled "Very Low Constraint" at one end and "Very High Constraint" at the other. Ratings were averaged, and the values obtained fell into one of three levels of semantic constraint located at roughly equal intervals along the semantic scale. Care was taken to make the semantic constraints similar for the high- and low-frequency words. Thus, the mean ratings for the low-constraint (LC) condition were 3.7 mm for the high-frequency words and 4.03 for the low-frequency words. For the medium-constraint (MC) condition, the means were 46.1 and 52.0 mm, respectively, and for the high-constraint (HC) condition, the means were 77.9 and 80.6 mm, respectively. None of the differences between high- and low-frequency words were significant. It is interesting to note that Grosjean's (1980) short and long contexts, as rated by the same judges, received the following values: In the short context, the means for high- and low-frequency words were 17.6 and 17.9 mm, respectively (n.s.), and in the long context, the means were 53.8 and 50.8 mm, respectively (n.s.). Thus, Grosjean's most constraining context (the long context) reached medium constraint only when compared with the present study.

The 22 complete sentences were recorded and gated in the manner described by Grosjean (1980): Each stimulus word was presented in each of the three constraint conditions; within each condition, the word was presented repeatedly, its presentation time (as measured from its onset) increasing at each successive gate. The only differences in the procedure used in this study were that, in the LC condition, the stimulus words were preceded by the definite article "the," instead of by silence, the first gate (the word "the") contained no burst or frication information from the stimulus word (and thus was considered to have a duration of 0 msec, as opposed to 30 msec of burst or frication), and the gate size after the first gate was increased by 50 msec instead of by 30 msec.

Procedure

The 24 subjects were assigned randomly to one of the three constaint conditions (LC, MC, and HC) and were run individually. They were instructed to listen to each presentation within each word set, to write down the word they thought was being presented, and to indicate how confident they were of their guesses by circling a number on a 1-10 scale (1 = very unsure; 10 = very sure).

Data Analysis

The isolation points of the words, defined as the points at which the subjects correctly guessed the stimulus words and did not change their guesses subsequently, were tabulated as in Grosjean (1980). In addition, the amount of a word needed to reach a confidence rating of 8 (on a scale of 10) was tabulated for each subject in each of the two frequency categories (high and low) and for each of the three constraint conditions. Analyses of variance, with frequency and constraint as fixed effects and subjects as a random effect, were run on the isolation-time data and the confidence-level data.

RESULTS AND DISCUSSION

Figure 1 presents the mean isolation times of the high- and low-frequency words as a function of the sentence constraint preceding the words. Also included in the figure are the results obtained by Grosjean (1980). (The no-context condition in that study was given an

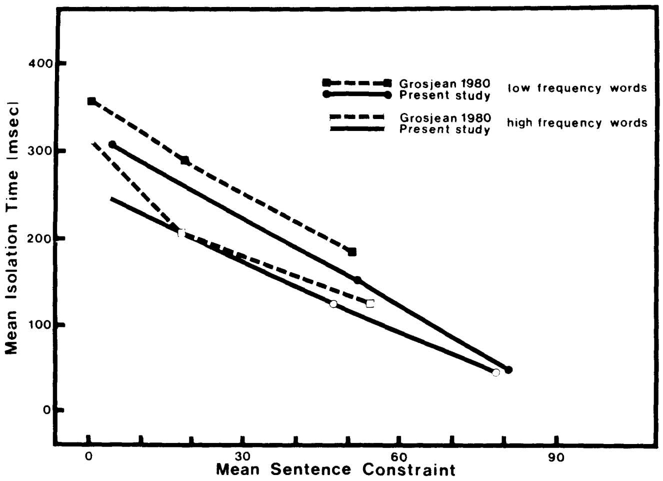

Figure 1. Mean isolation times for words of high and low frequency as a function of sentence constraint. In the present study (continuous functions), each point is the mean obtained across 11 two-syllable words and eight subjects. In the Grosjean (1980) study (discontinuous functions), each point is the mean obtained across 24 one-, two-, and three-syllable words and eight subjects.

arbitrary zero-constraint value). Main effects were found for both constraint and frequency, thus replicating Grosjean's findings. First, as the sentence became more constraining, the mean isolation time of words decreased substantially. We found global means of 275 msec for the LC condition, 136 msec for the MC condition, and 44 msec for the HC condition [$F(2,21) = 168.6, p < .01$]. Second, as the frequency of the word increased, isolation times decreased: Low-frequency words were isolated in 168 msec on the average, as compared with 135 msec for high-frequency words [$F(1,21) = 37.5$, $p < .01$]. What is especially interesting, however, is that a significant interaction was found between frequency and constaint. In the LC condition, there was a 66-msec difference between high- and low-frequency words. This difference was reduced to 29 msec in the MC condition and to 4 msec in the HC condition [$F(2,21) = 11.2$, $p < .01$]. And an a posteriori test (Tukey HSD, Kirk, 1967) showed that the difference between high- and low-frequency words in both the LC and MC conditions was significant ($p < .05$) but that it was no longer so in the HC condition ($p > .1$). An examination of the variance around the means shows that a floor effect is not artifactually creating the interaction. In fact, higher coefficients of variation were found in the HC condition (63% for the high-frequency words and 67% for the low-frequency words) than were found in the other two conditions (MC condition–30% and 22%, respectively; LC condition–6% and 9%, respectively). The interaction obtained is clearly seen in Figure 1, in which the results of the present study are compared with those obtained by Grosjean (1980). The difference in the height of the functions in the two studies is probably due to a number of factors, such as the facts that this study used only two-syllable words, whereas Grosjean used one-, two-, and three-syllable words, that the number of words used in the two studies was different (48 in Grosjean, as compared with 22 here), and that the two-syllable words were not the same in the two studies. It is interesting to note that if one puts aside Grosjean's less natural no-context condition, in which words were presented in total isolation, an interactive trend appears in this data: The difference between the isolation times of high- and low-frequency words is less in the long-context condition than in the short-context condition (see Figure 1).

An analysis of variance of the amount of a word needed to reach a confidence rating of 8 also showed main effects for constraint and frequency and a constraint x frequency interaction. First, in the LC condition, an average of 344 msec of the word was needed to reach the criterion level; in the MC condition, this was reduced to 228 msec, and in the HC condition, it was reduced to 100 msec [$F(2,21) = 56.5, p < .01$]. Second, an average of 235 msec of a low-frequency word was needed to reach a confidence rating of 8, whereas only 213 msec of a high-frequency word was needed to reach the same rating [$F(1,21) = 16.6, p < .01$]. And third, the difference between high- and low-frequency words was 38 msec in the LC condition, 27 msec in the MC condition, and 1.3 msec in the HC condition [$F(2,21) = 4.07, p < .05$].

From these two sets of results, we can conclude that if semantic context is sufficiently constraining, the effect of word frequency during the word-recognition process will be reduced, and even practically eliminated at high-constraint levels. Thus, word frequency joins a number of other properties of the word whose roles are affected by semantic constraint during word recognition. Some models of spoken-word recognition already take this into account (Morton's, 1969, logogen model, for instance), whereas others do not. Among these, we find Marslen-Wilson and Welsh's (1978) cohort model. One way this latter model could be modified would be to give every cohort candidate a frequency weighting so that high-frequency candidates would be "stronger" than their low-frequency counterparts and therefore easier to isolate and recognize. These weightings could then be modified by context. Thus, with enough semantic constraint, low-frequency words would become as "strong" as high-frequency words and hence as easily recognized.

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