Mutual Interference Between Two Linguistic Dimensions of the Same Stimuli

Ruth S. Day and Charles C. Wood

A single speech stimulus can be considered as a composite of values along many different dimensions. For example, a token of the syllable /ba/ will have a particular fundamental frequency, overall intensity, initial second-formant transition, formant values for the vowel, and so on. We are interested in the extent to which a given dimension can be processed independently of the others. An interesting and efficient way to study this problem is to select two dimensions and pit them against each other in a choice reaction-time paradigm. Subjects must attend to one dimension and ignore the other.

The dimensions studied in the present experiment were stop consonants (differing in place of articulation) and vowels. On each trial a single syllable was presented binaurally. In one task subjects had to target for the stop consonants, while in the other they had to target for the vowels.

Stop Consonant Task. Subjects pressed button #1 as soon as they heard /b/ and button #2 as soon as they heard /d/. This task was performed under two conditions of stimulus variation as shown in Figure 1. In the One-Dimension Condition, the target dimension (place of articulation for stop consonants) was the only one that varied: the stimuli were /ba/ and /da/.\(^1\) A mean reaction time of 400 msec was obtained. In the Two-Dimension Condition, both stop consonants and vowels varied: the stimuli were /ba, bae, da, dae/. Again, subjects had to identify stop consonants, but they also had to ignore irrelevant variation in vowels. They had difficulty in doing so, as reflected by increased reaction time: the mean rose to 450 msec.

Vowel Task. Subjects pressed button #1 as soon as they heard /a/ and button #2 as soon as they heard /ae/. The same two conditions of stimulus variation were used (Figure 1). In the One-Dimension Condition, the target dimension (formant values for vowels) was the only one that varied: the stimuli were /ba/ and /bae/.\(^2\) The mean reaction time here was 348 msec. In the Two-Dimension Condition, the same four stimuli as in the Stop Consonant Task were used. This time, subjects had to identify vowels and ignore irrelevant variation in stop

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+Haskins Laboratories and Yale University, New Haven.

++Neuropsychology Laboratory, Veterans Administration Hospital, West Haven, and Yale University, New Haven.

\(^1\)Or, in another block of trials, /bae/ and /dae/.

\(^2\)Or, in another block of trials, /da/ and /dae/.

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Figure 1: Stimulus arrays and button-press responses for each task and condition.
consonants. Again, this was a difficult task: mean reaction time rose to 414 msec.

The results of the experiment are summarized in Figure 2. We are interested in the extent to which reaction time for each target dimension increased in the Two-Dimension Condition. Both tasks yielded a sizeable increase. Thus there was a mutual interference effect: irrelevant variation in either dimension interfered with perception of the other.

How might these results be explained? One possibility is that the perceptual processors for place of articulation and for vowels are strongly interdependent. Such perceptual interdependence may well reflect known interdependence at articulatory and acoustic levels.

If this analysis is correct, then dimensions whose processors are not so strongly interdependent ought to yield a different pattern of results in this paradigm. Recently, we reported such a study (Day and Wood, 1972) in which the same stop consonants served as the linguistic dimension while fundamental frequency served as the nonlinguistic dimension. (Fundamental frequency is nonlinguistic in the sense that it does not carry linguistic information at the phoneme level in English.) The results are shown in Figure 3. Again, the Stop Consonant Task showed a large increase in reaction time in the Two-Dimension Condition. However, the corresponding increase for the Fundamental Frequency Task was much less: it barely reached statistical significance. Thus there was a unidirectional interference effect, in that it was much more difficult to ignore irrelevant variation in fundamental frequency while identifying stop consonants than vice versa.

The pattern of results for the stop consonant vs. fundamental frequency experiment suggest that these two dimensions behave in very different ways in the two-choice identification paradigm. When processing stop consonants, the listener cannot disengage his processing operations for fundamental frequency; however, when processing fundamental frequency, he can, to a considerable extent, disengage his linguistic processing operations. In fact, some subjects report that they are "unaware" of what consonants are occurring during the Fundamental Frequency Task; no one reports being unaware of pitch differences in the Stop Consonant Task.

It is also important to consider cases where both dimensions are non-linguistic. Wood (1972) used stimuli that varied in both fundamental frequency and overall intensity and obtained a mutual interference effect: both dimensions interfered with each other to the same extent. These results are comparable to those of the present experiment. Note that in the present experiment there were two linguistic dimensions, while in that of Wood there were two non-linguistic dimensions. A mutual interference effect may be a direct consequence of an interdependence of perceptual processors for the two dimensions. Thus far, this effect has occurred only for cases where both dimensions were from the same general class, that is, both linguistic or both nonlinguistic. The only cases where a unidirectional effect has occurred employed a dimension from each

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3 In a recent replication of this experiment, Wood (1972) obtained no increase for the Fundamental Frequency Task.
Figure 2: Mean reaction time for identifying stop consonants and vowels under two conditions of stimulus variation.
Figure 3: Mean reaction time for identifying stop consonants and fundamental frequency under two conditions of stimulus variation. (After Day and Wood, 1972)
of the two general classes.

The status of each dimension as linguistic or nonlinguistic, then, appears to be important in predicting outcomes of these two-choice reaction-time experiments. There are, however, other factors that may be involved. In the experiments reported thus far, information about both dimensions is available from the onset of the stimulus. Situations where this is not the case may behave very differently. For example, variation in voice onset time vs. fundamental frequency would delay the onset of fundamental frequency information relative to stop consonant information. By studying such a situation we will be able to determine the extent to which temporal processes are important in perceiving various dimensions of the speech signal.

Another factor of possible interest here is the relative discriminability of each dimension. Thus far we have used pairs of dimensions that are of roughly comparable discriminability. It will be of interest to see whether decreased discriminability of certain dimensions will alter the basic pattern of results more than others.

Summary. Subjects listened to simple consonant-vowel syllables that varied along two dimensions: place of articulation for stop consonants and formant values for vowels. When they had to identify values along one dimension, it was difficult to ignore irrelevant variation in the other dimension. This was true for both dimensions to the same extent. These results are compatible with an explanation that emphasizes the degree of interdependence between processors for linguistic and nonlinguistic dimensions.

REFERENCES
