

Category Boundaries for Linguistic and Nonlinguistic Dimensions
of the Same Stimuli*

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At the previous meeting of the Society we reported finding a shift in the category boundaries for tonal stimuli as a function of the relative number of occurrences of each stimulus in the series. No such shift was found in the category boundaries for synthetic stop consonant-vowel syllables. However, it could be argued that tonal stimuli are not appropriate control stimuli for speech sounds. To examine this possibility, identification functions were obtained for a series of synthetic CV syllables that varied simultaneously in both place (/ba/ to /da/) and pitch (/lo/ to /hi/). The distribution of occurrences of stimuli for the place and pitch dimensions were varied independently. When Ss judged pitch the category boundary shifted toward the more frequently occurring stimulus. In contrast, when they judged place no shift in the phonetic boundary was observed. These results agree with our previous findings and suggest that unlike the arbitrary categories for nonspeech stimuli, phonetic categories may have a naturally determined basis. These results are also discussed with regard to some recent findings on possible feature detectors in speech perception.

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There has been a great deal of work recently on the phenomenon of adaptation in speech perception. Using the selective adaptation paradigm first employed by Eimas evidence has been found for the existence of both phonetic and acoustic feature detectors in speech perception. Subjects exhibit a shift in the boundary locus of a CV identification function after listening to repeated presentations of an adapting stimulus. However, the selective adaptation results by themselves do not rule out alternative explanations of the shift phenomenon. One explanation of the shift effect is simple response bias. A response bias theory, such as adaptation level theory, would predict movement of an identification boundary toward the more frequently occurring stimulus. In the case of the selective adaptation paradigm, the subjects have been exposed to many more instances of the category from which the adapting stimulus is drawn. As a result the subject is biased to use the other category for responding during the identification test. This type of effect, known as a contrast effect, is well documented in visual perception and in the perception of simple tones.

At the previous meeting of the society in Los Angeles we reported results which examined subjects' identification functions for stop CV syllables and tones under two conditions. All subjects heard a series in which every stimulus occurred equally often. The second series

Slide 1 please

contained one stimulus that occurred twice as often as each of the rest

NON-SPEECH - INTENSITY

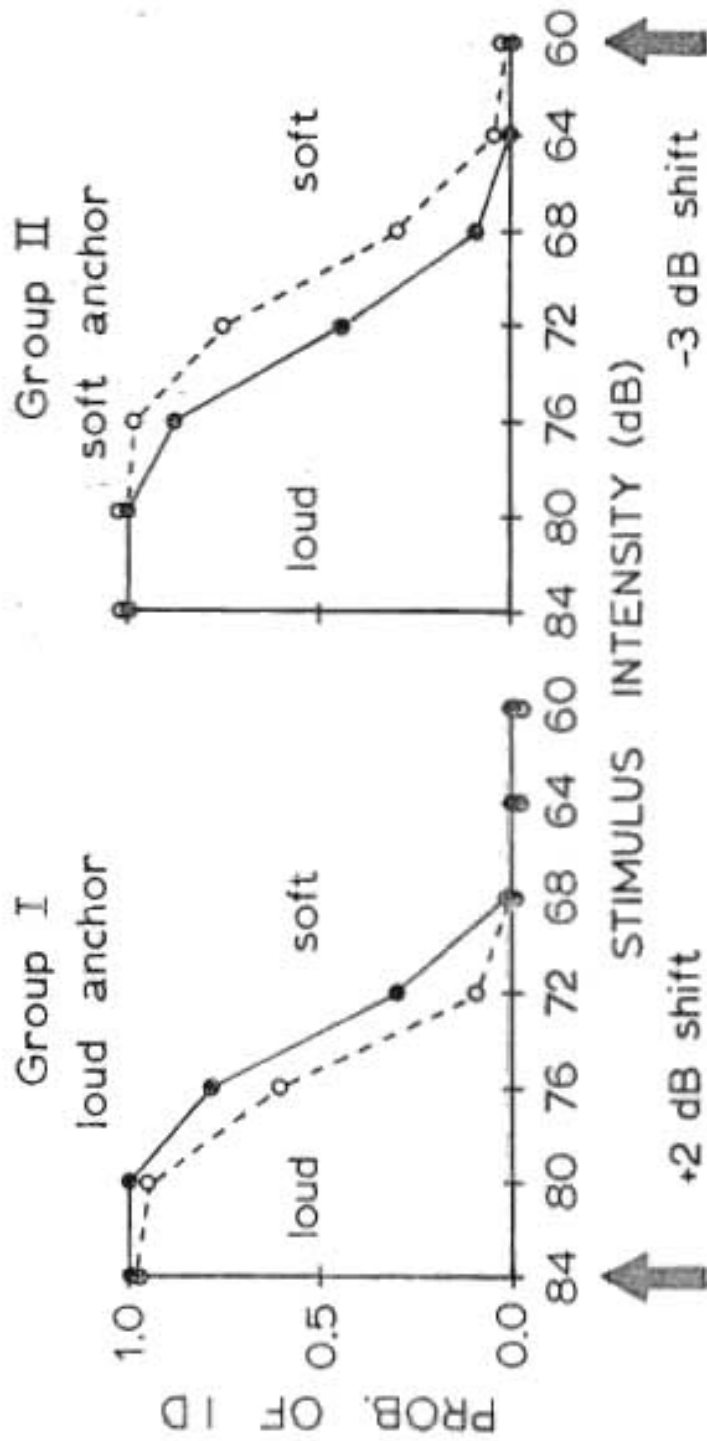


Figure 1.

of the stimuli. In this type of series, response bias theories predict a contrast effect. The identification boundary in the anchored or unequal series should shift toward the more frequently occurring stimulus, relative to the control condition. This result was found for the tones as shown in slide 1.

Slide 2 please

Under the same conditions, no shift was found for CV syllables varying in either place or voicing. Slide 2 shows this absence of a shift for a voicing series. We concluded that response bias theories which can provide an adequate explanation of the shift in the non-speech stimuli were an inadequate explanation of the category boundaries in CV syllables and that some other mechanism was mediating the category decision.

The data we presented in Los Angeles can be criticized on the grounds that pure tones were an inadequate control for the speech series. Tones are much simpler acoustically and they are also less familiar to the subjects than the speech sounds employed in these studies. In the present experiment, the judgment of place of production in a synthetic CV series is contrasted with the judgment of the fundamental frequency of the same identical stimuli. By using the same speech stimuli as their own control the comparison stimuli are neither simpler nor less familiar. The crucial difference now is whether the dimension being judged is carrying linguistic or non-linguistic information in the speech signal. The predictions of a response bias model such as adaptation level theory are

SPEECH - VOICING

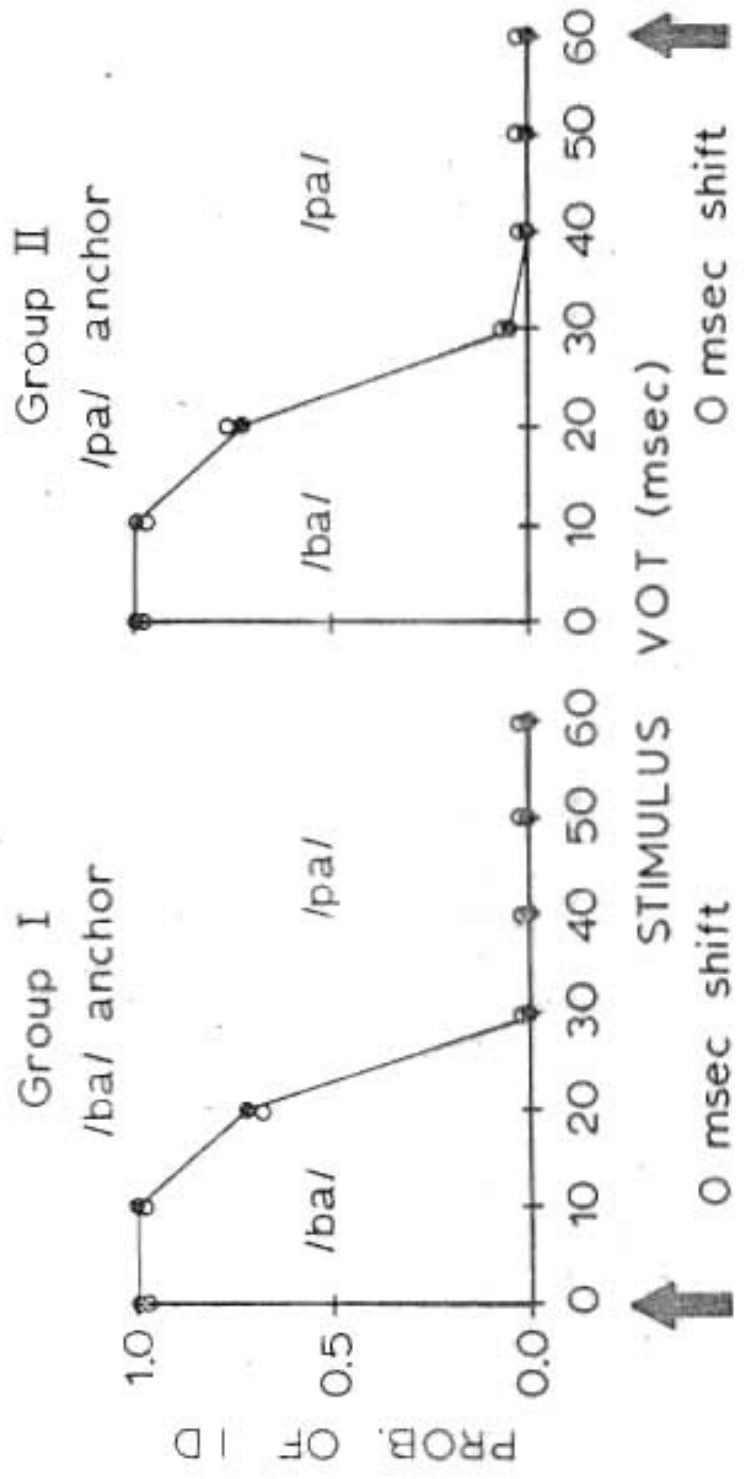


Figure 2.

the same as in our previous experiment. In the unequal series, the identification function should shift toward the more frequently occurring stimulus. This should be true whether the subject judges place or pitch.

Method

Slide 3 please

One set of synthetic three formant speech stimuli was used in this experiment. Two dimensions of the stimuli were varied orthogonally. The linguistic dimension was the place of production. The stimuli ranged perceptually from /bae/ to /dae/ in seven equal steps. The second and non-linguistic dimension was fundamental frequency or pitch. This was varied from 114 Hz to 150 Hz in 6 Hz steps. As indicated in slide 3, each value of pitch was paired with each value of place to produce a series of 49 stimuli in which no value on either dimension could be used to predict the value on the other dimension. These 49 stimuli were recorded on magnetic tape at Haskins Laboratories in random orders to produce five identification test tapes. In the control tape, each stimulus occurred twice. In the low anchor tape, each of the seven stimuli with a fundamental frequency of 114 Hz, shown in the dashed box, occurred eight times and the rest of the stimuli occurred twice each. In the bae anchor tape each of the seven stimuli with the bae place of production occurred eight times and the other stimuli occurred twice each. In similar fashion, high anchor, and /dae/ anchor tapes were also constructed.

Subjects were divided into four groups of nine subjects each. Each group heard the control tape and one of the anchor tapes. Subjects were told that they would be listening to the syllables /bae/ and /dae/. They listened to examples of the four corner stimuli (a low /bae/, low /dae/, high /bae/ and high /dae/) for practice. Subjects were told the relevant dimension to judge the stimuli on, pitch or place. In the pitch condition they were told to judge the stimuli as high or low pitch. In the place condition they were told to judge the stimuli as bae or dae.

Results and Discussion

Slide 4 please

Slide four shows the average identification functions for the two groups judging pitch. In group I, shown on your left, subjects heard the low anchor tape. The identification function shows a consistent shift toward the low stimulus, relative to the control function. Group II, which heard the high anchor tape, also shows a shift in the identification boundary. The shift is toward the more frequently occurring stimulus, the high pitched one. These results are in accord with the findings obtained earlier using tones.

Slide 5 please

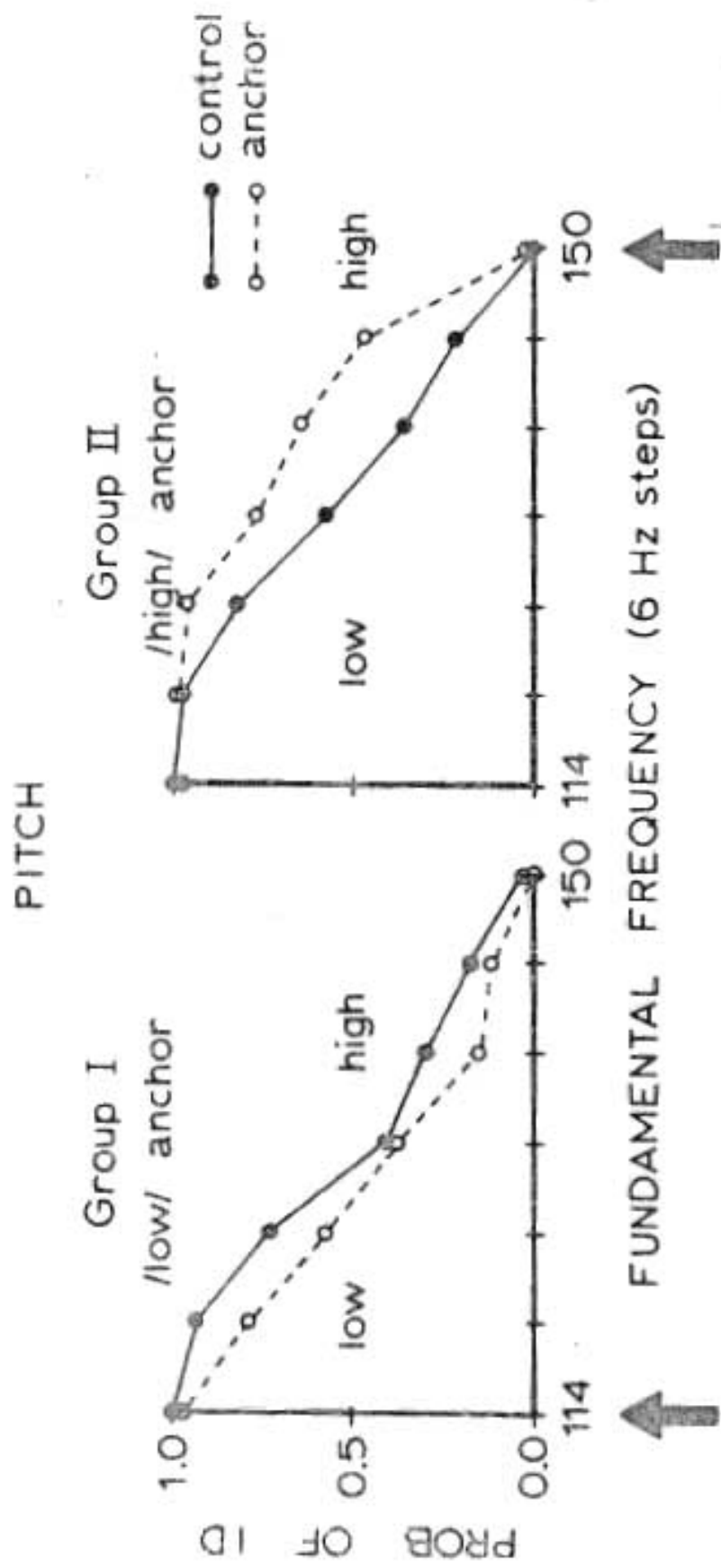


Figure 4.

SPEECH - PLACE

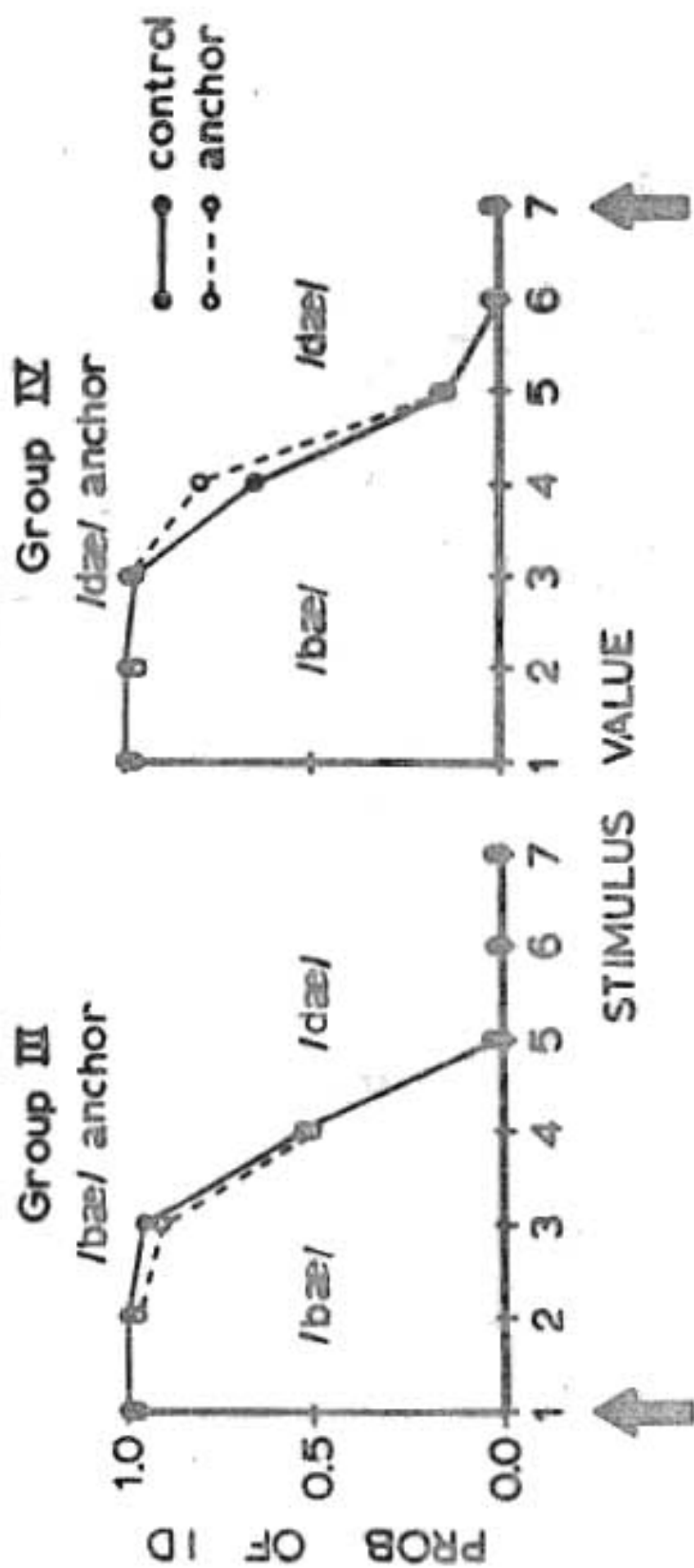


Figure 5.

Slide five shows the averaged identification functions for the two groups judging place. Group III heard the /bae/ anchor tape and Group IV heard the /dae/ anchor tape. These functions with unbalanced probabilities show no shift relative to the control functions. These results are also in accord with those found earlier.

An analysis of variance showed that both the shift and the shift by stimulus dimension interaction were significant beyond .001 level. There is a shift on the non-linguistic pitch dimension and no shift on the linguistic place dimension.

These results support our earlier conclusions that the category boundaries for the phonetic features of place and voicing are non-arbitrary and are not due to a simple partitioning of the stimulus continuum. Even when the same speech stimuli are employed, the non-linguistic dimension of pitch is quite vulnerable to response bias. We would like to suggest that these results rule out a response bias explanation of the category boundary shifts found with the selective adaptation paradigm. The results reported by Eimas, Cooper and others using the selective adaptation paradigm seem to be relatively early perceptual effects rather than changes in the decision mechanism. Whether the shifts are due to the fatiguing of specialized phonetic feature detectors or more generalized auditory processors awaits additional research. However, we think that we have made a good case for ruling out an obvious decision mechanism or response bias explanation of their results.

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In summary, when a non-linguistic pitch dimension is being judged, subjects show a shift in their category boundary when the probabilities of occurrence of different stimuli are unequal. The boundary shifts toward the more frequently occurring stimulus. No shift is found when subjects judge the linguistic dimensions of place of production or voicing.