Perception of Linguistic and Nonlinguistic Dimensions of Dichotic Stimuli*

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The notion that I would like to explore today is that we have different processing mechanisms for perceiving linguistic and nonlinguistic information. A major line of evidence supporting this notion comes from the dichotic listening literature. In dichotic listening a different message is presented to each ear at the same time. Typically, the subject is required to report "what he heard." Speech stimuli, such as digits, yield a right-ear advantage (Kimura, 1961). That is, subjects are more accurate in identifying stimuli presented to the right ear than those presented to the left ear. Nonspeech stimuli, such as melodies, yield a left-ear advantage (Kimura, 1964). That is, subjects are more accurate in identifying stimuli presented to the left ear.

These ear-advantage results in dichotic listening are highly replicable. How do we explain them? First, we know that language functions are handled primarily on the left side of the head. This is true for most right-handed people. An important source of evidence here is clinical: brain damage on the left side of the head usually results in language impairment, whereas comparable damage on the right side rarely interferes with language functions (for a recent review, see Geschwind, 1970).

Second, it appears that information presented to a given ear in dichotic stimulation goes primarily to the cerebral hemisphere on the opposite side of the head. Even though the ears are bilaterally represented in the two hemispheres, the pathway from a given ear to the hemisphere on the same side of the head seems to be suppressed under dichotic stimulation. Given these two assumptions (language in the left hemisphere, prepotency of crossed connections from ears to hemispheres), Kimura (1967) has explained the ear-advantage results in the following way. When both stimuli are speech, the right ear has direct access to the language-processing mechanism on the left side of the head. Meanwhile the left-ear stimulus reaches the right hemisphere and must then cross over to the left hemisphere via connecting fibers in order to undergo complete linguistic decoding. During this delay, there may be a decay in the clarity of the information, or the stimulus might undergo distortion during transmission across the connecting fibers. An analogous argument can be made for the case where both stimuli are nonspeech. The left-ear stimulus has direct access to the "nonspeech" functions of the right hemisphere, and so on. While this account is somewhat oversimplified for our purposes today, it does retain the basic features of the widely accepted Kimura model.

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Previous dichotic listening studies have retained the same experimental paradigm. They used speech stimuli in one condition and obtained a given set of results. They then used nonspeech stimuli in another condition and obtained a contrasting set of results. In the work I will discuss today, we have used a very different strategy. We have used only speech stimuli. But we have required subjects to track a linguistic dimension in one condition, and a non-linguistic dimension of the same stimuli in another condition.

**Method**

**Stimuli.** The stimuli were the consonant-vowel (CV) syllables /bæ/, /dæ/, /gæ/. Each had three pitch levels: high, medium, and low fundamental frequency. Thus there were nine stimuli in all: /bæ/-high, /bæ/-medium, /bæ/-low, /dæ/-high, /dæ/-medium, /dæ/-low, /gæ/-high, /gæ/-medium, /gæ/-low. They were synthesized on the parallel resonance synthesizer at the Haskins Laboratories. All syllables were 300 msec in duration and had identical intensity envelopes.

The /bæ/'s, /dæ/'s, and /gæ/'s differed from each other only in those cues known to be important for discriminating among voiced stop consonants. These cues are the direction and extent of the second (Liberman et al., 1954; Delattre et al., 1955) and third formant transitions (Harris et al., 1958). Stop consonants were selected to represent the linguistic dimension since they are the most highly encoded of all speech sounds (Liberman et al., 1967).

The highs, mediums, and lows differed only in their fundamental frequency. Each had a falling pitch contour; but began and ended at nonoverlapping frequency values. They began at 166, 130, and 96 Hz, respectively, and each fell 10 Hz. Fundamental frequency was selected to represent the nonlinguistic dimension since it provides little or no linguistic information at the phoneme level in English.

To summarize: the nine stimuli were classifiable according to two dimensions: a linguistic dimension (stop consonants) and a nonlinguistic dimension (fundamental frequency). Both dimensions were highly discriminable, as shown by the appropriate pre-tests.

**Tapes.** Dichotic tapes were prepared on the pulse code modulation system at Haskins. This system enables the experimenter to line up the onsets of dichotic stimuli with an accuracy of 1/2 msec. The stimulus pairs were varied in relative onset time. Sometimes the left-ear stimulus began first by 50 msec; on other trials the right-ear stimulus began first by 50 msec; and on remaining trials both stimuli began at the same time.

**Procedures.** The subject's task was to determine which stimulus began first on each trial. Thus, he had to make a temporal order judgment (TOJ). There were two conditions. 1) **Linguistic Task:** subjects had to report which stop consonant began first, /b/, /d/, or /g/.

2) **Nonlinguistic Task:** subjects had to report the pitch level of the leading stimulus, high, medium, or low. The same stimulus tapes were used for both conditions. All 16 subjects performed both tasks. They were right-handed, native English speakers and had no history of hearing trouble. All the appropriate counterbalancing procedures were observed, with respect both to test order and to the arrangement of items on the tape.
Percent Correct Temporal Order Judgment (TOJ) for the Linguistic and Nonlinguistic Tasks

Fig. 1
Results and Discussion

Linguistic Task. When subjects had to determine which stop consonant led, there was a right-ear advantage. That is, on those trials where the right-ear stimulus led, subjects were 41% correct in judging temporal order; on those trials where the left-ear stimulus led, they were 34% correct. Thus there was a 7% net advantage in favor of the right ear.

Nonlinguistic Task. When subjects had to determine the pitch on those trials where the left-ear stimulus led, subjects were 53% correct, while they were only 44% correct when the right-ear stimulus led. Thus there was a net 9% advantage in favor of the left ear. The results for both conditions are summarized in Figure 1.

Note that we have used the same stimuli in both tasks. Therefore the ear advantages could not have been determined by the nature of the stimuli. Instead it was the nature of the task requirements that determined the direction of the ear advantage: when subjects had to target for the nonlinguistic dimension of the same stimuli there was a left-ear advantage. These results are compatible with those of previous dichotic listening studies that used speech and nonspeech stimuli in separate conditions. Yet they go on to suggest that different processing mechanisms are involved in tracking linguistic and nonlinguistic dimensions of the same acoustic stimuli.

Despite the differences in ear advantage between the two tasks, the effect was not statistically significant. Perhaps the presence of variation in the irrelevant dimension attenuated the magnitude of these ear-advantage results. In order to study this possibility, we are currently retesting the same subjects. Again they judge the temporal order of stops in the Linguistic Task and fundamental frequency in the Nonlinguistic Task. However, the target dimension is the only one that varies. Hopefully, the ear-advantage data will be more sizeable in this situation.

There is another way to look at the ear-advantage data of the present experiment. Given that a subject had a particular value of an ear advantage on the Linguistic Task, did his score move "leftward" on the Nonlinguistic Task? The answer is yes: 12 subjects moved leftward, 3 moved rightward, and 1 showed no change. This shift in ear advantage was significant as shown by the Task x Ear interaction term in an analysis of variance (F = 4.76, p < .05).

There was another finding of considerable interest. Let's put the whole issue of ear advantage aside. Instead, consider over-all performance levels for the two tasks. Performance was better on the Nonlinguistic Task (49% correct) than on the Linguistic Task (38% correct) (F = 13.27, p < .005). This is what we would expect if an additional processor is needed in order to decode linguistic information. Both tasks require judgment of temporal order. However, the stimuli in the Linguistic Task may require more complicated analysis than do these same stimuli in the Nonlinguistic Task. These task differences support the notion that a special decoder is needed to handle linguistic information.

The specialized decoder notion receives additional support from some recent experiments in which we used a different experimental paradigm. Each trial consisted of a single binaural stimulus that subjects had to identify.
In the Linguistic Task they had to identify which stop consonant had occurred, while in the Nonlinguistic Task they had to identify which fundamental frequency had occurred. Our strategy was the same as in the present experiment: we used the same acoustic stimuli but required subjects to track different dimensions of these stimuli in the two tasks. Again, we obtained task differences, this time in terms of reaction time (Day and Wood, 1971) and neural activity (Wood, Goff, and Day, 1971).

To summarize the present experiment: subjects judged the temporal order of dichotic stimuli that varied along a linguistic and a nonlinguistic dimension. When subjects had to target for the linguistic dimension, there was a right-ear advantage. When they had to target for the nonlinguistic dimension there was a left-ear advantage. This shift in ear advantage between the two tasks was significant. Finally, over-all performance was better on the Nonlinguistic Task. These results, collectively, suggest that there are different processing mechanisms for linguistic and nonlinguistic information.

REFERENCES

Day, R.S. and Wood, C.C. (1971) Interactions between linguistic and nonlinguistic processing. (See this Status Report.)


1We plan to extend our study to native speakers of tone languages such as Thai since pitch level is a linguistic dimension in these languages.