Right-Ear Advantage for Musical Stimuli Differing in Rise Time

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ABSTRACT

Nonspeech stimuli differing in rise time, which resemble the sounds of plucked or bowed violin strings, were presented monaurally with contralateral noise, and reaction times for stimulus identification were measured. Reaction times were 12.8 msec faster when the stimulus was presented to the right ear than to the left ear, suggesting left-hemisphere involvement in the processing of these stimuli. This finding, considered along with other studies using the same stimuli, suggests that a single psychological mechanism is involved in the processing of the plucked and bowed sounds and consonant-vowel stimuli. In addition, the data support the theory that the dominant cerebral hemisphere is specialized for the processing of temporal variation.

The distinction between auditory and phonetic processes in the human perception of sounds has been a topic of much debate in recent years. Phonetic processing implies a mode of perception unique to speech stimuli. It is characterized by the fact that there is no one-to-one relationship between the acoustic stimulus and percept, and that perception appears to be modulated by rules of linguistic rather than acoustic organization (Liberman, Cooper, Shankweiler, and Studdert-Kennedy, 1967).

Wood (1975) listed six experimental operations whose results have been thought to converge on the distinction between auditory and phonetic processes. Three of these characteristic data patterns, however, have been found with a particular kind of nonspeech stimulus—sawtooth waves differing in rise time, which resemble the sound of a plucked or bowed violin string. The plucked and bowed sounds, like consonant-vowel (CV) syllables show: categorical perception

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Wood (1975) is cited here because he most clearly summarized the empirical evidence for the distinction between auditory and phonetic processes. However, the notion of special phonetic processing mechanisms was suggested considerably earlier by other researchers. See Studdert-Kennedy (1974) for a review of relevant research and a theoretical exposition of this viewpoint.

(Cutting and Rosner, 1974), referred to by Wood as the phoneme-boundary effect; boundary shifts due to selective adaptation (Cutting, Rosner, and Foard, 1976); and asymmetric interference with redundancy gain in a speeded classification task (Bleichner, Day, and Cutting, 1976). The remaining three experimental results cited by Wood are: right-ear advantage for identifying dichotically presented speech; right-ear advantage for reporting the temporal order of dichotic speech stimuli; and unilateral differences in average evoked potentials during the classification of linguistic and nonlinguistic dimensions. All three of these appear to reflect a single factor, that is, the lateralization of the cerebral hemispheres. It therefore seems quite pressing to determine which, if any, hemisphere is predominantly involved in the perception of plucked and bowed sounds, but so far data on this issue have been indecisive. Cutting, Rosner, and Foard (1975) found that dichotic presentation of the plucked and bowed sounds showed no significant ear advantage, but a null result in a dichotic study need not be considered conclusive, since it could result from the inadequate sensitivity and precision of the measure used.

One way of achieving a decisive finding where null results have predominated, is to use a potentially more sensitive measure, such as reaction time rather than accuracy. Springer (1973) has developed a means of reflecting hemispheric specialization through a reaction-time measure. She presented CV syllables monaurally with contralateral white noise and found a 14-msec advantage for stimuli presented to the right ear.

The purpose of the present study was to detect a potential ear advantage for plucked and bowed sounds using Springer's paradigm, with one modification: Springer had subjects respond only with the right hand, raising the possibility that the observed ear advantage might have been due to intercallosal transfer time rather than to hemispheric processing capacities. In the present study, therefore, both ear of presentation and hand of response were counterbalanced.

METHOD

Stimuli

The stimuli were identical to those used previously by Blechner et al. (1976). They were derived from the sawtooth wave sounds used by Cutting and Rosner (1974), originally generated on the Moog synthesizer at the Presser Electronic Studio at the University of Pennsylvania. The stimuli differed in rise time, reaching maximum intensity in either 10 msec (pluck) or 80 msec (bow). Using the pulse code modulation (PCM) system at Haskins Laboratories, the stimuli were truncated to 800 msec in duration and were stored on disc file in digitized form.

The white noise, which was to be presented contralaterally to the stimuli, was generated by a General Radio random-noise generator (Model 1390-A) and had a bandwidth of 20 kHz. The noise was digitized using the PCM system, truncated to a duration of 1000 msec, and then stored on disc file. The absolute levels of the noise and target stimuli (pluck and bow), as presented to listeners, were 80 and 70 dB SPL, respectively. All sounds were reconverted to analog form at the time of tape recording.
Tapes

All tapes were prepared using the PCM system. A display tape was prepared to introduce the subjects to the stimuli. The two kinds of stimuli (pluck and bow) were played in the same order several times, beginning with three tokens of each item, then two of each, and finally one of each.

Two binaural identification tapes were prepared, each with 32 tokens of the pluck and bow stimuli (16 of each) in random order.

Four dichotic test tapes were recorded. On one channel of each test tape, 60 tokens of the pluck and bow stimuli were recorded in random order with the constraint that every 10 stimuli contained equal numbers of pluck and bow stimuli. Thus, long runs of any one kind of stimulus were prevented. Sixty units of white noise were recorded on the second channel of the tape, with noise onset preceding stimulus onset by 50 msec. In addition, a 50 msec 1000 Hz tone that triggered the reaction time counter was recorded on both channels. The onset of this tone preceded the onset of the noise by 1.55 seconds. An interval of 2 seconds separated the offset of the noise from the onset of the next trigger tone. The intensity of the trigger tone was equivalent to the maximum intensity of the pluck and bow stimuli.

Four dichotic practice tapes were also prepared. These were identical in design with the test tapes but contained only 20 stimuli each.

Subjects and Apparatus

The 16 participants in the experiment included six males and ten females, ranging in age from 18 to 22 years. All were strongly right handed, as indicated by the five most reliable criteria found by Annett (1970). All reported no history of hearing trouble.

The tapes were played on an Ampex AG-500 tape recorder, and the stimuli were presented through calibrated Telephonics headphones (Model TDH39-300Z). Subjects sat in a sound-insulated room and responded with their index finger on either of two telegraph keys mounted on a wooden board. Throughout the experiment, the left key was used for bow responses, while the right key was used for pluck responses. The 50-msec pulse preceding each stimulus triggered a Hewlett-Packard 522B Electronic Counter. When a response on either telegraph key stopped the counter, the reaction time was printed on paper tape by a Hewlett-Packard 560A digital recorder for subsequent analysis. The listener's response choice was recorded manually by the experimenter.

Procedure

Listeners participated individually in a sound-insulated room. At the start of each session, they were informed of the general nature of the experiment and of the particular kinds of sounds that they would be asked to identify. They were told that the difference in rise time would be compared to the difference in sound between a plucked and a bowed violin string.

For preliminary training, subjects listened to the display sequence. They were then instructed on the mode of response, after which they listened to the display sequence twice more, responding to the sounds first with the left hand.
and then with the right. Next, they listened to the binaural identification tapes. Eight of the subjects responded to the first tape with the left hand and to the second with the right hand. For the other eight subjects, the order of responding hands was reversed.

Subjects were then told that they would hear the stimulus in one ear, to which they were to pay careful attention, while there would be noise in the other ear, which they should ignore. They were played a few samples from the dichotic tapes to familiarize them with the noise-stimulus combination. They then listened and responded to the four practice tapes, and, after a five minute rest period, to the four test tapes.

For each individual listener, the pluck and bow stimuli were always presented through the same headphone. Ear of presentation was alternated by having the listener reverse the headset. For eight of the participants the stimulus was presented through one of the headphones, while for the other eight it was presented through the opposite headphone.

There were four possible hand-ear configurations. The order of these conditions was determined by a balanced Latin square design, yielding four possible orderings that were administered to four subjects each. The four practice and test tapes, however, were always played in the same order, to prevent any possible confusion between the effects of the random orders and the hand-ear configurations.

Subjects were instructed to respond as quickly and accurately as possible. In the final data analysis, only the last 50 test trials in each block were considered, the first ten functioning as warm-up trials to stabilize performance. The listener, however, was not told that the first ten trials would not count.

**RESULTS**

All of the subjects were able to identify the pluck and bow stimuli accurately. In the binaural identification trials, no listener made more than 4.7 percent errors.

For the reaction time data of the task with contralateral noise, median reaction time was calculated for each block of test trials for each subject. An analysis of variance was performed on these medians, with order of conditions considered as a between-subject factor, and hand and ear of presentation as within-subject factors.

The mean across subjects of individual medians for right-ear presentation of the stimuli was 662.5 msec, while for left-ear presentation, the mean was 675.3 msec. This 12.8-msec advantage for right-ear presentation was statistically significant, \( F(1,12) = 5.69, p < .05 \). Collapsed over ear of presentation, mean right-hand response was 665.0 msec, while mean left-hand response was 672.8 msec. This 7.1-msec difference, however, was not statistically reliable. All other main effect and interaction terms were not significant.

Accuracy in this experiment was quite high. The mean error rate was 0.9 percent. An analysis of variance on the error data showed no significant main effects or interactions.
DISCUSSION

The Issue of Special Processing for Phonetic Dimensions

The finding of a significant right-ear advantage for the identification of plucked and bowed sounds is very similar to the results for CV syllables, and suggests left-hemisphere involvement in the processing of both kinds of sounds. When the present data are considered along with other studies using plucked and bowed sounds, the parallels between this kind of nonspeech sound and CV syllables are quite compelling. The nonspeech stimuli have yielded all of the basic data patterns cited by Wood (1975) as evidence converging on the distinction between auditory and phonetic processes. The plucked and bowed sounds—like the speech stimuli—show asymmetric interference with redundancy gain in the speeded classification task, categorical boundary effects, selective adaptation of the category boundary, and evidence of left-hemisphere specialization. Considered together, this constellation of results with nonspeech stimuli leads one to question the existence of a special mode of processing for speech stimuli (Liberman, 1970), at least on the phonetic level. One might perhaps argue that identical results with CV syllables and plucked and bowed sounds do not guarantee identical perceptual mechanisms. Nevertheless, at the present time, it seems most parsimonious to account for these results in terms of a single mechanism for processing complex auditory dimensions that cue significant distinctions for a subject, rather than assuming, as Wood (1975) did, that results reflect separate mechanisms for phonetic and higher level auditory processes. It should be emphasized, however, that the conclusion proposed here does not challenge the notion of unique perceptual processes on other levels of linguistic organization.

Relevance to Specific Theories of Hemispheric Specialization

Although the present data have their greatest impact when considered within a set of converging experimental operations, they are relevant also to the specific question of the functions of the two cerebral hemispheres. Kimura (1967) suggested that the left and right hemispheres might be specialized, respectively, for verbal and nonverbal stimuli. This proposition has since been questioned by the discovery of right-ear advantages for nonspeech stimuli (for example; Halperin, Nachshon, and Carmon, 1973). The present study adds another set of data that contradicts the verbal-nonverbal dichotomy of hemispheric specialization.

Bever (1975) has suggested an alternative viewpoint, stressing the importance of different kinds of processing, rather than intrinsic stimulus variables in accounting for lateral asymmetry. He hypothesizes two modes of perception, analytic and holistic, for the left and right hemispheres, respectively. This view purports to account for individual differences in hemispheric specialization for melodies as a function of musical ability (Bever and Chiarello, 1974). However, the analytic-holistic distinction as currently formulated has little predictive value for plucked and bowed sounds. After looking at the data, one might suggest that they require analytic processing. After all, the stimuli differ in rise time, a small difference that might easily be missed if the stimulus were treated more globally. Other evidence, however, contradicts this view. Cutting et al. (1976), for example, have demonstrated that while rise time cues the distinction between plucked and bowed sounds, it is not an entirely sufficient cue. Fully half a second of waveform after stimulus onset is required for
the items to be identified properly. Thus, the whole of the stimulus is necessary for perception, and this fact would suggest a holistic mode of processing.

It may be more accurate to account for the present data based on the stimuli's acoustic nature rather than in terms of processing strategy. One particularly important acoustic property of the plucked and bowed stimuli in terms of hemispheric specialization is their characteristic rapid acoustic variation. Several studies have implicated the resolution of temporal variation as a left-hemisphere mechanism, both in audition (Halperin et al., 1973; Cutting, 1974) and vision (Goldman, Lodge, Hammer, Semmes, and Mishkin, 1968; Carmon and Nachshon, 1971). It may well be that the rate of shift in amplitude which distinguishes the plucked from the bowed sounds, is responsible for the greater left-hemisphere involvement.

REFERENCES


