Selective Listening for Dichotically Presented Stop Consonants and Vowels*

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For some time now dichotic listening experiments have been used to explore cerebral asymmetries in perception. This work began with the discovery by Kimura\(^1\) that when different spoken words are delivered simultaneously to the two ears over earphones, recall is more accurate from the ear opposite the hemisphere dominant for speech, this being the right ear in most persons. The left ear, however, is the more efficient for report of dichotically presented nonverbal stimuli such as melodies, environmental sounds and sonar signals.

Dichotic presentation is a necessary condition for the occurrence of these lateral differences in perception. Experiments by Corsi\(^2\) and by Halwes and Shankweiler\(^3\) with temporally-overlapping stimuli presented to one ear alone have failed to yield lateral differences, indicating that ear asymmetry is produced by competition between ears and not merely competition between stimuli.

There is much supporting evidence, based partly upon study of patients with focal lesions of the cerebral hemispheres, that laterality effects in dichotic listening result jointly from

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functional asymmetries of the cerebral hemispheres in man and from the greater strength of the crossed than the uncrossed auditory pathway. It is clear that the right ear advantage in recall of dichotically presented words occurs because the right ear has the better path to areas of the left cerebral hemisphere known to be specialized for speech. For this reason we and our colleagues at Haskins Laboratories wished to exploit the dichotic listening technique to learn more about the functions of the speech areas and about the neural basis of speech perception. Many interesting questions had not been asked. Do acoustic patterns which have the sound structure of speech but no meaning give a laterality effect? If the laterality effect occurs for nonsense speech, is the right ear favored, as with meaningful words, or the left ear, as with patterned non-verbal sounds?

Shankweiler and Studdert-Kennedy investigated these problems and showed that a substantial right ear advantage could be obtained when the task was to report back single pairs of nonsense syllables differing between the ears in the initial stop consonant. This result supports the view that perception of sound structure as well as other aspects of language depends upon lateralized cerebral processes. Do all speech sounds give a right ear advantage? Much research indicates that stop consonants are more complexly encoded in the sound stream than are vowels. Shankweiler and Studdert-Kennedy found that competing vowels are substantially less lateralized than competing stop consonants, suggesting that vowel perception need not engage the specific speech processing apparatus of the dominant hemisphere.

The main purpose of the experiment which I will now describe was to determine whether the findings of Shankweiler and Studdert-Kennedy would be repeated with a further simplification of the task. Because we were interested in using the dichotic listening technique to study the perception of speech, we wished in our
experiments to place a minimal burden on memory. In the experiments of Kimura, Bryden and others, several pairs of words were presented on each trial. The Shankweiler and Studdert-Kennedy results with single pairs of syllables showed unequivocally that the laterality effect is not tied to serial presentation of stimuli. Kimura has shown that report of both ears is not a necessary condition for the occurrence of lateral differences in perception. We therefore presented single pairs of CVC nonsense syllables, as before, with instructions to subjects to attend to a particular ear and ignore the stimulus in the other ear. Subjects were to report a designated ear for a block of trials then switch attention to the other ear for an equal number of trials. We were interested to see whether a right ear advantage would be obtained and whether stop consonants would be more lateralized than vowels when only one response is required. We were also curious about the accuracy with which subjects would be able to identify the ear of arrival of stimuli such as these, which contrast between the ears in only one phone.

Method. The recorded stimuli were prepared by Shankweiler and Studdert-Kennedy and had been used in their experiment described in SR (13/14). Thirty-six CVC syllables were recorded on magnetic tape by a male speaker, a trained phonetician. The syllables consisted of each of the six stop consonants [p, t, k, b, d, g] followed by each of the vowels [i, ɛ, ã, a, ɔ, u] and ending in [p]. The stop consonant test contained all pairs of these syllables in which consonants differed but vowels were alike, for example, the pair [bap] - [dap]. The vowel test contained all pairs in which vowels differed but consonants were alike, for example, [bap] - [bup]. The tapes were prepared as follows: One member of each pair was recorded on each of two channels on magnetic tape. By use of a modified tape deck, the syllable onset in each pair could be synchronized. Each test
contained 180 pairs of syllables in random order, with six seconds between pairs.

The subjects were ten students from the University of Connecticut. All had normal hearing and considered themselves right-handed. They listened with earphones to the consonant tape and the vowel tape four times each, making a total of 720 trials for each test. Earphones were reversed in half the runs with each tape. The subjects were asked to attend to a particular ear for 90 consecutive trials, then they were to switch attention to the other ear.

The subjects were told that each trial would contain two different syllables, delivered simultaneously, one at each ear, alike except for the vowel or initial stop consonant, depending on the test. They were to record the stop consonant (or vowel) presented to a specified ear, guessing if necessary. Their responses were restricted to the set of six alternatives appropriate to the test.

**Results and Discussion.** Despite instructions to attend equally often to the two ears, most subjects recorded syllables delivered to the right ear more often than syllables delivered to the left ear. For CVC syllables contrasting in the initial stop consonant, one of the ten subjects significantly favored the left ear, two showed no difference between ears, and the remaining seven had right ear advantages ranging from 12% - 41% (all significant with p < .01 or better). When syllables differed in the vowel, only three subjects produced a significant right ear advantage. Seven subjects had nonsignificant effects on the dichotic vowel test. Thus, laterality effects were obtained for more subjects when stop consonants differed than when vowels differed. No subject showed as large a laterality effect for vowels as for stop consonants. Figure 1 gives the percentage of trials on which each ear was recorded, averaged over the 10 subjects and the two
attention conditions.

We have found, as Kimura did, that instruction to attend to only one ear does not eliminate the laterality effect in speech perception. By obtaining immediate recall of a single phoneme on each trial, we have minimized the role of serial processes and memory in determining the frequency with which each ear is recalled. Clearly, these laterality effects have a perceptual basis.

Figure 2 shows how often the right and left ear were reported, depending upon the ear to which the subjects were attending. When instructed to report the right ear they were more often correct than when instructed to report the left for both stop consonants and vowels. They were also more efficient in excluding syllables from the unwanted ear while attending to the right ear.

The subjects were much more accurate in selective monitoring of either ear for the vowels than for stop consonants. When vowels competed, there were 76% more correct responses than intrusions from the unattended ear. When consonants competed, there were many more intrusions: correct responses exceeded intrusions by only 19%. The subjects clearly had difficulty in determining the ear of arrival of the stop consonants. Not only did the right ear intrude when the left was being monitored, as might be expected, the left ear was often reported when the right was being monitored. The pattern of results shown in Figure 2 is typical of that displayed by most of the subjects individually.

These results suggest that a difference in ear of arrival is not necessarily a sufficient condition for distinguishing between simultaneous stimuli.

If stop consonant identification is mediated primarily by one cerebral hemisphere, then confusions between ears may occur because the two ears are competing for identical processing areas. Similarly, the easier localization of vowels may
reflect the involvement of both hemispheres in vowel identification. It is also possible that confusions between ears for dichotically presented stop consonants result from a loss of acoustic information when the stops are decoded. An example of the inaccessibility to the listener of the acoustic representation of stop consonants is seen in the phenomenon of categorical perception. Experiments conducted at Haskins Laboratories have demonstrated that subjects cannot discriminate among tokens of the same stop consonant phoneme which differ acoustically along a particular dimension, although variations along this dimension are easily discriminated across the phoneme boundary. For vowels, on the other hand, subjects can discriminate intraphonemic acoustic variations. It is possible that the inability to localize by ear dichotically presented stop consonants is another manifestation of the perception of these sounds as linguistic categories rather than in terms of their acoustic properties.

In summary, a right ear advantage has been shown for dichotically presented pairs of syllables which differ in only one phoneme by use of a radically simplified experimental method which eliminates serial order effects. Larger laterality effects are obtained for stop consonants than vowels regardless of whether one or both ears are reported on each trial. Ear confusions occur much more frequently in identification of stop consonants than vowels. It is not yet clear whether this difference can be explained acoustically or whether it is yet another manifestation of the operation of a speech mode of perception.
Footnotes


7. Kimura, op. cit. (Fn. 5).