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Laterality effects in diotic listening

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Abstract. Three pairs of simultaneous consonant-vowel syllables were presented over two loudspeakers, and the subject attempted total recall. With the loudspeakers situated to the left and to the right of the subject, the message from the right is better recalled. With one loudspeaker in front of the subject and the other on one side, the message from the middle is better recalled. These results are discussed in terms of the interpretations which have been proposed for right ear superiority in dichotic listening to verbal material.

1 Introduction

Kimura (1961) found that when different verbal stimuli are presented simultaneously to the two ears the stimuli which arrive at the ear opposite the dominant hemisphere are more efficiently recognized. She attributed the effect to functional prepotency of the contralateral over the ipsilateral auditory pathway. Later, Sparks and Geschwind (1968) examined a patient with complete section of the neocortical commissures and found a complete suppression of the ipsilateral input by the contralateral input. They suggested that the longer pathway via the *corpus callosum* is normally the most important one for reporting verbal material presented to the ear ipsilateral to the dominant temporal lobe. This addition to Kimura's original assumption leads to an interpretation of ear differences which is now widely accepted (Studdert-Kennedy and Shankweiler, 1970): sounds which enter the ear more directly connected with the processing centres have an advantage over sounds which simultaneously enter the other ear. This interpretation, based on structural properties of the auditory system, assumes that the critical factor in ear differences is whether the sound does or does not reach a particular ear.

The evidence from dichotic presentations is, however, not sufficient to support this assumption. A message presented monaurally to one ear also appears to originate from the corresponding half of the external space. Right-ear advantage might thus reflect better processing of messages coming from the right as well as better neural connections of the right ear. Kinsbourne (1970) has recently put forward an interpretation of ear advantages in terms of attentional bias, postulating that the activation of one cerebral hemisphere directs attention to the contralateral space. In particular, differential left-hemisphere activity during verbal tasks would bias attention to the right of the median plane. This interpretation is supported by the results of an experiment where tachistoscopic detection was enhanced in the right visual field during retention of verbal material, not in a control condition. It accounts for the well established association between ear advantage and laterality of the speech centre (Kimura, 1961), while avoiding the ear-of-entry assumption of the Kimura-Sparks-Geschwind interpretation.

The present paper reports a first attempt to separate the effects of spatial position from those of ear of entry by the use of diotic presentations over loudspeakers. This, however, provides a one-sided test only. If no lateral difference were to be found in the recall of two simultaneous messages coming one from the right, the other from the left, the spatial-position interpretation would become untenable. On the other hand, the finding of a lateral difference would not necessarily invalidate an ear-of-entry

interpretation, since there are intensity differences between the two messages at the two ears which might be relevant. This point will be considered in detail in the discussion. Conditions with one message coming from a position in front of the subject and the other from one side were also included, because it was thought that some result patterns could provide crucial information. If, for instance, recognition performance on the stimuli coming from the middle had been intermediate between the performances on the lateral stimuli, this would have been inconsistent with an ear-of-entry interpretation.

The study consisted of presenting sequences of three pairs of consonant–vowel (CV) syllables, the members of the pairs coming from two out of three loudspeakers situated respectively to the left, to the right, or in front of the subject, and asking the subject to recall as many syllables as he could.

2 Method

2.1 *Material and experimental situation*

In each trial three pairs of nearly simultaneous syllables were presented at the rate of two pairs per second. The 36 possible CV syllables formed by pairing each of the six stop consonants: /*b, d, g, p, t, k*/ with each of the six vowels: /*a, e, i, ɔ, u, y*/ were used with the same relative frequency. Each syllable appeared the same number of times on the two tape tracks. No syllable was presented twice in any trial and the same pairing did not occur more than once in the entire test.

All the syllables were individually recorded by one male speaker. The tape was cut into 500 ms strips, each with one syllable, and all syllables began at nearly the same position from the beginning of the strip. The strips were joined together to make up sequences of three syllables; two such sequences were played back simultaneously on two synchronized tape recorders (Revox A77) and fed to the two channels of a third one. The tape was edited, with each train of syllables preceded immediately by a 150 ms burst of a 1000 Hz tone, itself preceded at a 3 s interval by an announcement of the serial number of the trial. The tapes were later monitored on a Siemens Oscillomink graphic recorder. The recordings showed that about 50% of onset asynchronies were in the range 5–10 ms; in no case did they exceed 30 ms.

The material was played back on a Revox A77 tape recorder connected to three loudspeakers (Isophon HSB 15/8) which were situated at head level, 1 m from the nearest ear of the subject, one in front and the other two in the frontal plane passing through the aural axis, one on the left and one on the right. The subject sat in an adjustable stool, before a table, with the head position fixed by a dental bite. Three lamps, one representing each of the three loudspeakers, were situated under the middle loudspeaker. Two were lit before each trial to signal the loudspeakers about to be used.

The testing was conducted in a quiet though not sound-proof room, about 3 m x 4·5 m. To ensure that the apparent direction of the sources was not seriously affected under these conditions, three blindfolded persons were asked to point at the sources under the three conditions used in the experiment. The directions were judged quite accurately.

2.2 *Subjects*

Forty-six students who reported no hearing defect were tested. They were paid on the basis of the percentage of correctly recalled syllables. After the experimental session all filled out a handedness questionnaire which was a French adaptation of Oldfield's (1969) list. The thirty-six subjects whose responses are reported were found to be right-handed with a laterality quotient (LQ) greater than +70 (twenty-six

were right-handed for all the activities listed in the questionnaire: LQ = +100). Their ages were in the range 19–31. Fourteen were male and twenty-two female. Ten other subjects who had been tested had LQ < +70, and their data were discarded.

2.3 *Procedure*

Each subject participated in one session consisting of 12 practice and 108 experimental trials. At the beginning he was shown a list of all possible syllables. He was told to write down immediately after each trial as many syllables as he could, in any order, on a response sheet. He was encouraged to guess when he was not sure. The experimenter stopped the tape recorder after each trial and restarted it after the subject had written down his response and was again in the listening position, biting the dental bite.

Three presentation conditions were used: one message from the left and one from the middle (L–M), one from the middle and one from the right (M–R), and one from the left and one from the right (L–R). Each subject took part in 36 trials under each condition, 18 during the first half and 18 during the second half of the test, in random order. The session started with 4 practice trials under each condition. The effects of tape recorder channel, loudspeaker, and trial difficulty were balanced out across the subjects: half the subjects received channel 1 from the left in the L–M condition, from the middle in the M–R condition, and from the right in the L–R condition; the other half received channel 2 from these locations. Six subjects were tested with each of the six possible allocations of the three loudspeakers to the three positions; and the conditions were presented in such an order that each trial was passed under one of the three conditions by one third of the subjects.

3 Results

The proportion of syllables correctly identified for each spatial position under each condition is shown in table 1. The differences between the performances obtained for the two locations were evaluated using a t test. For L–R condition right location is better than left location ($t = 3{\cdot}19$, d.f. = 35, $p < 0{\cdot}005$ by a one-tailed test, since right-side advantage was predicted). For L–M and M–R conditions middle location is better ($t = 2{\cdot}97$, $p < 0{\cdot}01$, and $t = 4{\cdot}32$, $p < 0{\cdot}001$, by two-tailed tests).

The differences can also be evaluated by classifying the subjects according to the location for which they obtained the better score under each condition (table 2). The comparisons R > L, M > R, and M > L are all significant above $p = 0{\cdot}05$.

Table 1. Proportion of syllables correctly recalled (%).

Condition	Position			Mean
	L	M	R	
L–R	33·9	-	39·3	36·6
M–R	-	38·4	32·2	35·3
L–M	30·0	40·0	-	35·0

Table 2. Distribution of subjects according to spatial differences.

Condition	Position giving better performance				p sign test
	L	M	R	none	
L–R	9	-	25	2	0·005, one-tailed
M–R	-	24	10	2	0·03, two-tailed
L–M	6	30	-	0	0·0002, two-tailed

The proportions of correct responses averaged over locations (table 1) suggest that the overall performance is slightly better in the L–R condition than in the other two conditions. Analysis of variance followed by application of Scheffe's test supports this conclusion, with $p < 0{\cdot}025$.

The data were examined for the possibility of an evolution during the session. In none of the conditions does the ratio of the performance scores for the two locations change systematically from the first to the second half of the session.

4 Discussion

Differences associated with the relative locations of the sources can be observed in a situation where subjects listen diotically to two competing messages. A message coming from the right is more efficiently recognized than one coming from the left, and a message coming from a position in front of the listener is better recalled than one coming from either the right or the left. This suggests an empirical relation between recognition performance and spatial location, with a maximum somewhere near the median plane and a progressive asymmetrical decrease towards the sides.

Our finding of an advantage of the frontal message is consistent with the fact observed by Treisman (1964) that it is easier to shadow a binaural message in the presence of an irrelevant message presented monaurally to the right ear, than to shadow a monaural message from the right in the presence of a binaural irrelevant one. Treisman's result and ours are probably two manifestations of the same phenomenon.

Whatever the mechanism underlying the superiority of the frontal position, it has an obvious adaptive value, since it gives priority to the sounds coming from the person or object one is looking at.

As was noted in the introduction, the finding that messages coming from the right loudspeaker have an advantage over those coming from the left one is consistent with an interpretation of right ear superiority as one particular aspect of a general relation of speech processing performance to apparent source of the messages. Following this kind of interpretation, the mechanism responsible for recognition priorities would operate after the stage of stereophonic fusion, using as a selection criterion the spatial cues obtained at that stage.

On the other hand our results contradict the strict version of the ear-of-entry interpretation, which states that the only determinant of recognition performance is whether the message does or does not reach the critical ear. No effect of spatial location would be predicted for diotic listening where both messages always reach the two ears. But few specialists would want to defend this extreme version, and most would probably be willing to admit that timing and relative intensities of the messages can also play some role. A message from one lateral loudspeaker arrives at the nearest ear at most 0·7 ms sooner than the message from the opposite side if the two messages are perfectly synchronized; but as the synchronization errors in our material are much greater and their direction is randomly distributed between the tracks, timing cannot produce any systematic effects. A more serious possibility is an effect of intensity differences at each ear between messages coming from opposite sides. Right side superiority in the left–right condition might be related to the right message reaching the critical right ear at a higher intensity level than the left message. The same factor would explain the superiority of the middle location over the left one. The two results could then be interpreted on the basis of a hypothesis combining (*a*) superiority of the direct pathway to the language centres over the commissural pathway, and (*b*) competition of messages travelling through that pathway, with prepotency of the more intense one. In the middle–right condition, however, both messages reach the right ear at the same intensity level, and the only factor favouring

the message from the middle would be that it reaches the left ear at a higher intensity level than the message from the right. To account for the performance difference observed in this condition, one would then have to assume that competition with prepotency of the more intense message applies also to the commissural pathway.

No definite conclusion regarding the mechanism of lateral asymmetry can thus be reached on the basis of the present results. The only hypothesis that has been clearly refuted is that the only determinant is ear-of-entry, and that intensity is irrelevant. We are thus left with the choice between (*a*) a spatial-position interpretation, and (*b*) an elaborate ear-of-entry interpretation where the performance difference depends primarily on the intensity at which the messages reach the ear opposite the language centres, and secondarily on the intensity at which they reach the other ear. A stronger test of interpretation (*b*) would be provided by a study of stereophonic presentations through earphones with phase differences only, and this will be reported in a further paper.

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