The effects of ventriloquism on the right-side advantage for verbal material*

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Abstract

Subjects were asked to recall one of two simultaneous messages coming from hidden loudspeakers situated either at 90° or at 45° from the median plane to the left and to the right. They were told that the messages were coming from two visible dummy loudspeakers which were also situated either at 90° or at 45°. Pre-stimulus cueing of the side to be recalled was given. Significant right-side advantage was obtained in the 90° real-fictitious condition, not in the other conditions. These results show that right-side advantage can be obtained with presentation over loudspeakers and unilateral recall, and dismiss a purely structural or purely cognitive view of lateral asymmetries in audition. Role of structural and cognitive factors is discussed.

Introduction

Kimura (1961) has found that when different verbal stimuli are presented simultaneously to the two ears of subjects with left hemispheric dominance, the material presented to the right ear is better recalled than that presented to the left ear. The reverse effect was found for a small group of subjects with right hemispheric dominance. Subsequent work, controlling for order of report and biases of voluntary attention (Bryden, 1963; Myers, 1970; Gerber and Goldman, 1971), or using a single syllable pair for identification (Shankweiler and Studdert-Kennedy, 1967), showed that this asymmetry is a true perceptual asymmetry.

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Kimura (1961, 1964, 1967) attributed the laterality effect favoring the ear opposite to the dominant hemisphere to functional prepotency of the contralateral over the ipsilateral auditory pathway. With monaural listening, the slightly greater effectiveness of the contralateral connections would not be great enough to permit a difference in performance. But when different stimuli are presented to the two ears, as in dichotic listening, the impulses arriving along the ipsilateral pathway would be partially occluded in the common neural units which, according to Rosenzweig (1951), respond mainly to contralateral stimulation; a greater loss of information from the ipsilateral path would give rise to a greater number of recognition errors for the message presented in the ipsilateral ear.

Suppression of the ipsilateral input by the contralateral input in dichotic listening has been demonstrated by work on split-brain patients (Sparks and Geschwind, 1968; Milner, Taylor and Sperry, 1968). Sounds entering the ear ipsilateral to the dominant hemisphere reach the processing centers through the minor hemisphere and the *corpus callosum*, therefore, with greater loss of information, weaker or later than sounds which simultaneously enter the ear more directly connected with the dominant temporal lobe. Thompson, Samson, Cullen and Hughes (1973) have suggested a model which considers (1) the two ears as independent channels, (2) some form of 'gating out' of the information transmitted via the ipsilateral pathway and (3) the addition of noise to the left ear channel information as a consequence of the neural processing necessary to accomplish interhemispheric relay. The interpretation put forward by Kimura, Sparks *et al.*, Thompson *et al.* and others for the ear differences is based on structural properties of the auditory system and assumes that the critical factor in obtaining a laterality effect is whether sounds do or do not stimulate the ear privileged for the kind of information to be extracted.

The well-established crossed relation between 'dominant ear' in dichotic listening experiments and dominant hemisphere have inspired a considerable body of experimental work on speech perception with the use of the 'right-ear advantage' effect (Studdert-Kennedy and Shankweiler, 1970; Haggard, 1971; Darwin, 1971). In order to get relevant and interpretable data on speech perception processes it was not indispensable to deal with the mechanism of the dominant ear-dominant hemisphere crossed relation. This may partly explain why the model put forward by Kimura remains largely accepted, although modern developments in cognitive psychology would normally lead to eyeing it somewhat suspiciously.

The right and left auditory nerves are obvious channels. But channels in the mind may not correspond exactly to channels in the brain. Simon, Small, Ziglar and Craft (1970) found that reaction times to a high- or a low-pitched tone were slower when the tone came in the ear opposite to the responding hand than when it came in the ear ipsilateral to it; reaction times were also slower when, by presenting the tone binaurally and manipulating the interaural phase, it seemed to come from the opposite side than when it seemed to come from the ipsilateral side. This means that the interference effect must be attributed to direction of the apparent source, not to the ear stimulated *per se*. Morton, Crowder and Prussin (1971) showed the effect of a binaural suffix on the recall of an auditorily presented sequence of items to be much less than that of an ipsilateral suffix and to be comparable to the effect of a contralateral suffix. Rejection of the suffix does not involve turning off one ear but rather segregating its trace on the basis of apparent spatial origin. These results suggest that signals are labelled according to the region of auditory space from which they originate and not according to the ear stimulated.

Experiments on the 'right-ear advantage' effect have used dichotic and (more rarely) monaural presentations, so in both cases each message has been presented to one ear and to one ear only. However a message presented to one ear alone also appears to come 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.

In a first attempt to separate the effects of spatial position from those of ear of entry, Morais and Bertelson (1973) used diotic presentations of two simultaneous verbal messages over loudspeakers. Three pairs of simultaneous consonant-vowel syllables were presented on each trial, 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 was found to be better reproduced. In that situation, the speech sounds reached both ears, but with natural time and intensity differences. Thus an ear-of-entry interpretation was not necessarily invalidated. If time differences could not be relevant because of larger onset asynchronies between the two signals of each pair, an effect of intensity differences by themselves and not by their role in localization became a more serious possibility. In order to clarify this point, Morais and Bertelson (1975) tested subjects with stereophonic presentations of two simultaneous messages using only time differences between stimulation of the two ears by the same message. Pre-stimulus cueing of the side to be recalled in each trial was given. A right-side advantage was obtained, showing that laterality effects can arise as a consequence of the spatial position of the speech sounds. The effect observed was, however, significantly smaller than with dichotic presentation. This discrepancy was tentatively accounted for by differences in apparent localization of the sources; in the stereophonic condition using time differences only, sounds seemed to come frequently in the frontal areas of the head, whereas in the dichotic situation they were almost always located near the ears.

The foregoing experiments show that Kimura's interpretation of ear differences in dichotic listening is too simple. However, a spatial position phenomenon is not inconsistent with another form of structural interpretation if the terms contralateral and ipsilateral pathway are thought of as relating halves of auditory space to the two cerebral hemispheres instead of ears. The shift from ear to region in auditory space is supported by electrophysiological data. Rosenzweig (1954) showed that the magnitude of the electrical response at either hemisphere was greater on the side opposite to the location of a sound, this localization being achieved by time or intensity differences between two clicks delivered independently to the two ears. The further over to the side the sound was heard, the greater the difference between the activity at the two hemispheres. An interpretation of lateral asymmetries in audition which would integrate these data would consider the link between dominant side and dominant hemisphere as proceeding entirely from the constraints of the auditory system. Alternatively, one might consider a cognitive interpretation which would stress control processes of sensory stimulation by the central structures, like the one put forward by Kinsbourne (1970, 1974). This interpretation attributes asymmetries to the fact that activation of one cerebral hemisphere by tasks calling for its specialized cognitive skills directs attention to the contralateral side of space. Conversely, the hemisphere contralateral to the direction of attention is temporarily more efficient than the hemisphere ipsilateral to that direction.

One way of assessing the relative importance of structural and cognitive factors may be provided by separating the effects of believed and actual lateral separation of sound sources on the lateral asymmetry phenomenon. In the experiment reported here, subjects were presented with two simultaneous sequences of three consonant-vowel syllables coming from hidden loudspeakers situated either at 90° or at 45° from the median plane to the left and to the right. They were told that the messages were coming from two visible dummy loudspeakers which were also situated either at 90° or at 45°. The four combinations of the two real and the two fictitious sources were used. Thus, in two conditions, sound origin and visual cues were separated by 45°. This angular separation was unnoticed (ventriloquism effect), although it exceeded the maximum value generally indicated for the perception of a single unitary event (Witkin, Wapner and Leventhal, 1952; Jackson, 1953). This is probably because not one but two simultaneous 'unitary' events were occurring in this experiment, and each was difficult to identify in the presence of the other.

The subject had to recall only one side on each trial, and pre-stimulus cueing was given. This procedure is advantageous because it controls for biases of voluntary attention. Broadbent (1974) reported an experiment he conducted with M. Gregory in which two simultaneous messages were presented over loudspeakers; instructions were given for half the messages to be recalled with the right-side message first and for half in the opposite order, and no lateral asymmetry was found. As in Morais and Bertelson (1973) subjects attempted total recall in any order; one accessory aim of the present experiment was to ensure that a right-side advantage could be obtained with presentation over loudspeakers and unilateral recall.

Right-side advantage was thus predicted when both real and fictitious loudspeakers were situated at 90° from the median plane. No lateral asymmetry, or a smaller right-side advantage, was expected when both real and fictitious loudspeakers were situated at 45°.

Information about the relative importance of structural and cognitive factors would be provided by comparing results of the misleading and non-misleading conditions corresponding to each position of real loudspeakers. Right-side advantage when both real and fictitious loudspeakers were at 90° contrasting with no lateral asymmetry, or a smaller one, when real loudspeakers were at 90° and fictitious ones at 45° would indicate the intervention of some cognitive factor and would be inconsistent with a purely structural interpretation. On the other hand, right-side advantage when real loudspeakers were at 45° and fictitious ones at 90° contrasting with no lateral asymmetry, or a smaller one, when both real and fictitious loudspeakers were at 45° would indicate that cognitive factors may generate, or increase, by themselves, the lateral asymmetry phenomenon.

Method

Material and experimental situation

The tape used by Morais and Bertelson (1973) provided the material for the present experiment. On each trial three pairs of nearly simultaneous consonant-vowel syllables were presented at the rate of two pairs per second. Each train of syllables was preceded immediately by a 150 ms burst of a 1000 Hz tone, itself preceded at a 3 sec interval by an announcement of the serial number of the trial. CV syllables, recorded by one male speaker, were 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/. No syllable was presented twice on any trial, and the same pairing did not occur more than once in the entire test.

The subject sat on an adjustable chair with his back to the experimenter and the tape recorder, facing 0° and looking at a small colored circle on the wall. The room was quiet though not sound-proof, and walls and ceiling were black. The subject wore a head-light with a narrow beam. He was instructed to keep the beam on the colored circle during trials. Two tables were placed obliquely and symmetrically to the sagittal plane passing through the fixation point-subject axis. Two loudspeakers (Isophon, HSB 15/8) were placed on each table, in such a position that one was situated at 45° from the latter axis, the other at 90°, at a 1.30 m distance from the subject at about shoulder height. These four loudspeakers were connected to a Revox A 77 tape recorder and were the real sources, two on the left and two on the right of the subject. On each side, a horizontal board was placed on top of the loudspeakers, and the whole was covered with dark cloth. The real loudspeakers were thus invisible. Two dummy loudspeakers were placed on the boards, one on the left side and one on the right side, and were visible to the subject. According to the experimental condition, the experimenter placed them at 90° or at 45° from the median plane. The experimenter sat at a table behind the subject, slightly to the left for half the subjects and slightly to the right for the other half.

Subjects

Thirty-four right-handed students who reported no hearing defect were tested. After the experimental session they were questioned about their impressions concerning source location. Two of these subjects noticed at times the spatial discordance between sound origin and visual cues, and their data were discarded. Ages of the subjects whose data were kept were in the range 15–28. Six were male and twenty-six female.

Procedure

Pilot testing, in which the tape was presented twice, showed that sessions should be short and without trial repetition in order to prevent awareness of the spatial discordance. Thus, in the experiment reported here, each subject participated in one session which lasted about 30 minutes during which the tape was played once for 12 practice trials and 96 experimental trials. At the beginning the subject was shown a list of all possible syllables.

Trials were presented under four conditions: (1) real and fictitious loudspeakers at 90° on either side of the median plane (condition R 90-F 90); (2) real loudspeakers at 90°, and fictitious loudspeakers at 45° (condition R 90-F 45); (3) fictitious and real loudspeakers at 45° (condition R 45-F 45);

(4) real loudspeakers at 45° and fictitious loudspeakers at 90° (condition R 45-F 90). Half the subjects received the first 48 experimental trials with fictitious loudspeakers at 90°, then the experimenter placed them at 45° for the last 48 experimental trials; the reverse order was used for the other half. For each of the F conditions, there were eight blocks of six trials. For half the subjects, the first and the fourth block (as the fifth and the eight) were presented with real loudspeakers at 90° and the second and the third block (as the sixth and the seventh) with real loudspeakers at 45°; the reverse order was used for the other half. The practice trials were presented with fictitious loudspeakers in the position used during the first half of experimental trials; they were presented in four blocks of three trials with R conditions in the same order as in the experimental trials.

The subject was told before each block of six trials which side he should listen to. Half the subjects had these instructions in the order LRLR in each group of four blocks, the other half in the order RLRL. Each subject listened to blocks of practice trials in the same order as he listened to blocks of experimental trials.

The subject was instructed to write down immediately after each trial, on a response sheet, the three syllables he had heard from the side previously indicated. Instructions for ordered recall and for leaving no blanks (i.e., 'Guess when uncertain') were given. The subject returned to the listening position, facing 0° and looking at the fixation point, after he had written down his response and before announcement of the following trial.

Subjects always received the same channel through the loudspeaker they were supposed to listen to. Real loudspeakers which were on one side for half the subjects were put on the corresponding positions of the other side for the other half.

Results

The percent of errors scoring procedure, put forward by Krashen (1972) as the least biased by guessing measure of relative degree of lateralization was used in this experiment. The percent of errors score expresses the error score for a particular side as a percentage of the total number of errors. The error score for one side is the number of syllables presented to that side which were not recalled correctly.

The left side percent of errors score (left side errors/total errors), averaged over the 32 subjects, is shown in Table 1 for each of the four conditions. The hypothesis that left side percent of errors score is greater than 50 was tested for each condition by a one-tailed t test. Right-side advantage was clearly

Table 1. *Distribution of subjects according to side differences in number of correct syllables, left-side percent of errors* scores and t tests on these scores*

Condition	Side giving better performance (score: Number of subjects)			Mean left-side percent of errors	t test ($df = 31$)
	Right	Left	None		
R 90-F 90	23	7	2	52.91	3.50 $p < 0.005$
R 90-F 45	17	15	0	49.39	–0.40 ns.
R 45-F 45	17	11	4	50.60	0.80 ns.
R 45-F 90	17	13	2	50.92	0.92 ns.

* Left-side percent of errors $= \frac{\text{left-side errors}}{\text{left-side errors + right-side errors}} \times 100.$

Table 2. *Distribution of subjects according to side differences in number of intrusions, mean differences left-right in number of intrusions and t tests on differences between intrusions in the left and intrusions in the right*

Condition	Side admitting more intrusions (score: Number of subjects)			Mean difference left-right in number of intrusions	t test ($df = 31$)
	Left	Right	None		
R 90-F 90	19	6	7	1.13	2.50 $p < 0.001$
R 90-F 45	14	13	5	0.19	0.50 ns.
R 45-F 45	12	13	7	0.56	1.47 ns.
R 45-F 90	20	10	2	0.56	1.14 ns.

significant in condition R 90-F 90. The means of the other three conditions were not significantly different from 50. Table 1 shows also the distribution of subjects according to the side for which they obtained the better score under each condition.

Table 2 shows the difference between the number of intrusions from the right-side message in the left-side message and the number of intrusions from the left-side message in the right-side message, averaged over the 32 subjects for each of the four conditions. This difference was significant on a one-tailed t test in the condition R 90-F 90, and non-significant in the other three conditions. Table 2 also shows the distribution of subjects according to the side in which fewer intrusions were made.

Table 3. *Proportion of syllables correctly recalled (%), averaged over the two sides under each condition*

Condition	Percent of correct syllables
R 90-F 90	44.2
R 90-F 45	45.1
R 45-F 45	38.9
R 45-F 90	39.0

Questions asked previously about the structural and cognitive interpretations of lateral asymmetry were framed as two independent planned comparisons. These were performed both on the left side percent of errors scores and on the differences between the number of intrustions in the left-side message and the number of intrusions in the right-side message. For both types of scores, the mean of the R 90-F 90 condition was significantly greater than the mean of the R 90-F 45 condition on a one-tailed test (respectively, $t = 1.68$, $df = 93$, $p < 0.05$, and $t = 3.48$, $df = 93$, $p < 0.0005$); the mean of the R 45-F 90 condition was not significantly different from the mean of the R 45-F 45 condition ($t = 0.15$ and $t = 0.00$).

Percent of syllables correctly recalled averaged over the two sides under each condition is shown in Table 3. Performance averaged over the two R 90 conditions was better for 27 subjects, and worse for 5 subjects, than performance averaged over the two R 45 conditions. This difference was significant beyond $p = 0.001$ by a sign test.

Discussion

When simultaneous messages came from 90° to the left and 90° to the right without misleading the subject (who was asked to reproduce only one particular message) performance was better for the right-side message. This result replicates one previously found by Morais and Bertelson (1973); furthermore, it clearly demonstrates that such an effect is not a mere artifact of the order of report or of biases of voluntary attention. With a procedure controlling for these additional sources of variance, both stereophonic presentation through headphones (Morais and Bertelson, 1975) and presentation over loudspeakers (the present experiment) have now yielded right-side advantage.

When messages came from 45° to the left and 45° to the right with dummy loudspeakers in the same positions, no significant right-side advantage was observed. This finding might be considered as supporting the view held by Morais and Bertelson (1975) that the differences in the size of the effect between their different presentation conditions (in particular, between dichotic presentation and stereophonic presentation using time differences only) were related to the degree of source lateralization.

The novelty of the present experiment is the use of misleading conditions regarding the spatial origin of the sounds. It must be noted that performance averaged over the two sides seems to be a function of the lateral separation of real sources and to be unaffected by misleading the subjects or not. Focusing attention on a point 45° away from the real source did not impair performance when real loudspeakers were at 45°; it only changed distribution of the correct responses between the sides when they were at 90°. The fact that the overall accuracy for the misleading and the corresponding non-misleading conditions were of the same magnitude warrants comparison of degrees of lateral asymmetry between these conditions.

Comparison between the R 90-F 90 condition and the R 90-F 45 condition showed that right-side advantage vanished if sources were believed to be situated at 45° from the median plane rather than at 90°. This outcome was observed with two types of scores, percent of errors and number of intrusions. It argues of course against an interpretation based exclusively on structural factors. It seems impossible to explain the mechanisms of the dominant side-dominant hemisphere crossed relation only in terms of a constant feature of the auditory system, for instance, the greater activity evoked in one particular temporal lobe by sounds coming from the opposite side.

On the other hand, for real sources at 45° no right-side advantage was created or increased by putting the dummy loudspeakers at 90° from the median plane. This fact is not consistent with a purely cognitive interpretation which would only take into account apparent position.

According to Kinsbourne's model, directing attention to a target at 90° to the right should increase the activity of the left hemisphere, whereas directing attention to a target at 90° to the left should decrease it to the same extent. The hypothesis that orientation of attention towards one side may determine differences in level of activity between the hemispheres and in that way give rise to lateral asymmetry in performance is not supported by the present results. In fact, the condition with both fictitious and real sources at 90° was the only one to give a clear right-side advantage. Moreover, when real loudspeakers were at 45°, relative performance for a particular side estimated either on the basis of percent of errors or on the basis of intrusions was manifestly independent of position of the fictitious loudspeakers. It seems, therefore, that the false belief of the listener about the spatial origin of the messages and the corresponding orientation of his voluntary attention may annul but not create a lateral asymmetry in performance. Some auditory correlate of 90° sources as well as belief in this direction must be present in order to obtain a right-side advantage effect.

One aspect of the auditory correlates of lateralized signals is probably a stronger projection on the left-dominant hemisphere of signals from 90° to the right than of signals from 90° to the left. This neural feature could be potentially able to raise lateral differences in performance. However, even if the processing of lateralized signals is constrained by the relative strength of their left-hemisphere projection, particularly when they are delivered simultaneously, the present work shows that the effects of neural constraints are not transferred directly in performance but undergo the action of cognitive control processes. On the other hand, the auditory correlate of signals which is necessary for the occurrence of a laterality effect does not need to be a feature privileging by itself one particular side. This feature might be anything else but the presence or absence of a neural representation for sounds with a particular spatial origin. Let us consider one of Kinsbourne's hypotheses, i.e., that relative degree of activation of the two hemispheres determines shifts of covert attention in the lateral plane. We may adapt it to the present results by supposing that, following left-hemisphere activation, more attention capacity is automatically distributed to a limited region in the right side of the subject; this attention imbalance would be a potential one, and before determining its effect, capacity should be spatially allocated by an effort of voluntary attention which depends also on information derived from the other senses and from expectancy. By directing attention away from the preferred region as a consequence of a false belief, the capacity supplement would be lost or shared out in some way between the two signals. Conversely, if by a false belief attention is allocated to the preferred region without a cortical correlate of stimulation in that region, no supplement of capacity would be available for the processing of the signal actually presented.

At this point in the discussion, it is interesting to reconsider the classical structural model of laterality effects. We have undertaken two stages of its reductionist approach. The first was to deduce a psychological phenomenon from the functional organization of a neurological system. The second was to delete the real auditory world in which this functional organization evolved. Disposing of electrophysiological data on the microstructure of the auditory system, it was tempting to account for lateral asymmetries in audition in terms of numbers of neural units responding to stimulation in each ear. As Putnam (1973) pointed out, the way by which psychology – a 'higher-level' science – is reduced to the laws of its 'lower-level' science is the theory of the brain and nervous system. The process of reductive analysis has been rewound in the case of the 'ear differences' phenomenon by showing, *first,* that we privilege positions in space, not the laboratory right ear, and *second,* that structural factors are an element of the explanation, not *the* explanation.

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Résumé

Les sujets devaient rappeler un de deux messages provenant de haut-parleurs cachés qui étaient situés à gauche et à droite du plan médian, soit à 90 degrés, soit à 45 degrés. Il leur était dit que les messages provenaient de deux faux haut-parleurs, visibles et situés aussi soit à 90 degrés, soit à 45 degrés. L'indication du côté à rappeler était donnée avant la présentation. Une supériorité du côté droit significative a été obtenue dans la condition avec haut-parleurs réels et fictifs à 90 degrés, mais pas dans les autres conditions. Ces résultats montrent qu'on peut obtenir une supériorité du côté droit avec présentation à travers des haut-parleurs et rappel unilatéral, et permettent de réfuter une interprétation purement structurelle ou purement cognitive des asymmétries latérales dans l'audition. Le rôle des facteurs structuraux et cognitifs est discuté.