CEREBRAL DOMINANCE AND THE PERCEPTION OF VERBAL STIMULI[1]

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IN A PREVIOUS STUDY (Kimura, 1961) the writer demonstrated that, when different digits are presented simultaneously to the two ears, the following results are obtained:

(1) Unilateral temporal lobectomy impairs the recognition of digits arriving at the ear contralateral to the removal, a finding in agreement with other studies (Jerger & Mier, 1960; Sinha, 1959).

(2) Over-all efficiency, as measured by the total number of digits correctly reported from both ears, is affected by left temporal lobectomy but not by right temporal lobectomy. Both before and after operation patients with lesions of the left temporal lobe are inferior to those with lesions of the right, even when the groups are matched for digit span.

These facts were interpreted to mean that the crossed auditory pathways in man were stronger or more numerous than the uncrossed and that the left temporal lobe played a more important part than the right in the perception of spoken material.

For all groups of subjects studied, regardless of the site of the lesion, the preoperative score was higher for the right ear than for the left. Since the right ear was presumably more strongly connected to the left temporal lobe than was the left ear, this finding suggested that verbal material arriving along this pathway had an advantage in being more reliably transmitted to the hemisphere which was dominant for speech representation. It would then follow that, in subjects with speech represented in the right hemisphere, recognition of verbal material arriving at the left ear should be more efficient. This was the hypothesis investigated in the present study.

METHOD

Subjects

The *Ss* were 120 patients at the Montreal Neurological Institute with epileptogenic lesions of various parts of the brain. Of these, 107 had speech represented in the left

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hemisphere, 13 in the right hemisphere. The 13 subjects in the second group were found to have speech on the right by the technique of injecting sodium amytal into the internal carotid artery of one side, thereby temporarily disrupting the functions of that hemisphere (Wada & Rasmussen, 1960). The right and left sides were injected on different days, with contralateral hemiplegia and hemianopia resulting from each injection. Dysphasia, however, occurred only after injection of the dominant hemisphere.[3]

In the left-dominant group not all subjects were given the sodium amytal test, since it vas administered only in doubtful cases. It is possible therefore that one or two subjects are included in this group who actually have speech represented on the right. (Any such cases would tend to minimize differences between groups rather than enhance them.) All left-handers were given the test, however, and the proportion of right-handers with speech on the right is very low in this patient population (Penfield & Roberts, 1959).

Thirteen normal control subjects were also tested. They were all right-handed.

Procedure

The procedure has been described in detail in the previous paper (Kimura, 1961). A dual-channel tape-recorder with stereophonic ear-phones was used for the test. Digits were presented through these ear-phones in groups of six in such a way that half the digits came to the left ear, half to the right. After each group of six numbers, the subject reported everything he h ıd heard, in any order he liked. For the greater part of the test the six numbers were presented as three pairs, that is, two different numbers were presented simultaneously to the two ears, in a manner first introduced by Broadbent (1956). In all cases, different material was presented to each ear. There were 32 groups of six digits, making a total possible score of 96 for each ear.

Results

Table I presents data for five groups of subjects classified according to the origin of their seizures, and for a group of normal control subjects. It demonstrates clearly that the right ear is more efficient than the left regardless of the site of the lesion. This effect was confirmed for the normal group also ($p < .02$, difference t test) but it is somewhat less marked, due perhaps to the higher over-all efficiency. The five groups in Table I, exclusive of normal controls, make up the left-dominant group. Table II compares the relative efficiency of right and left ears for this group and

TABLE I

Preoperative Mean Scores

Group	Left ear	Right ear
Left temporal	76.8	81.5
Right temporal	83.4	88.0
Bitemporal	77.9	80.2
Frontal	82.7	86.4
Subcortical	76.5	85.5
Normal	90.25	92.25

[3]Throughout this paper the ter.n "dominant" will be used to refer to the hemisphere in which speech is represented.

TABLE II

HEMISPHERE DOMINANCE AND MEAN SCORES FOR THE TWO EARS

Locus of speech	*N*	Left ear	Right ear	Right minus left
Left hemisphere	107	76.64	83.01	6.37
Right hemisphere	13	85.00	74.85	−10.15

for the 13 subjects with speech in the right hemisphere. These data indicate that when speech is represented in the left hemisphere, the right ear is more efficient, and when speech is represented in the right hemisphere, the left ear is more efficient.

It also happens that most of the subjects with speech on the left were right-handed, and most of the subjects with speech on the right were left-handed. It therefore seemed important to determine the relation, if any, between handedness and the relative efficiency of the two ears. Accordingly, these two groups were broken down into two more groups on the basis of handedness, and the results are shown in Table III.

TABLE III

SPEECH VERSUS HANDEDNESS
(MEAN SCORES)

Handedness	*N*	Left ear	Right ear
	Left-dominant group		
Right-handed	93	77.03	83.73
Left-handed	10	72.50	77.00
	Right-dominant group		
Right-handed	3	83.67	81.67
Left-handed	9	85.00	71.44

Ambidextrous subjects were omitted from this analysis. It is clear that the ear opposite the dominant hemisphere is more efficient, irrespective of handedness. This is borne out by a statistical analysis of the difference scores between ears. A simple analysis of variance of this difference score for the four groups yields an F ratio of 10.42 ($p < .001$). Subsequent t tests demonstrate a significant difference between the two left-handed groups with speech in opposite hemispheres ($p < .001$) and no difference between the two left-dominant groups with opposite handedness ($.40 < p < .50$). Thus handedness is not a factor in producing these results.

In the group of 13 subjects with speech on the right, nine had widespread damage to the left hemisphere. This was presumably an important influence in producing the development of speech on the right, since the proportion of left-dominant subjects with such damage is very low.

The right hemisphere in these nine cases is both the dominant hemisphere and the intact one, and the superiority of the left ear may be due to either of these factors. That is, the left ear may be more efficient in the right-dominant group because the large lesion in the left hemisphere has depressed performance on the contralateral (right) ear. There are two points against this. First, two of the right-dominant subjects had damage only to the right, the dominant hemisphere, and two more had only minor damage to the left hemisphere. All four of these subjects were more efficient on the left ear. Secondly, seven subjects were selected from the left-dominant group because they had widespread damage to the left hemisphere, and three of the thirteen subjects were dropped from the right-dominant group because they had a high degree of such damage as judged by the presence of weakness or smallness on the right side of the body. These two selected groups were then compared for the relative

TABLE IV

MEAN SCORES OF TWO GROUPS MATCHED FOR LEFT-HEMISPHERE DAMAGE

Locus of speech	*N*	Left ear	Right ear	Right minus left
Left hemisphere	7	70.7	83.0	12.3
Right hemisphere	10	84.4	78.4	−6.0

efficiency of right and left ears (Table IV). Again, it is apparent that the ear opposite the dominant hemisphere is the more efficient despite the presence of severe left-hemisphere damage in both groups ($p < .02$).

DISCUSSION

It appears that when different verbal stimuli are presented to the two ears, those stimuli which arrive at the ear opposite the dominant hemisphere are more efficiently recognized. This is consistent with the view presented in a previous paper that the crossed auditory pathway is the more efficient one, and that the dominant temporal lobe plays an important part in the elaboration of speech sounds. Stimuli arriving at the right cochlea will presumably send more impulses to the left Heschl's gyrus, and hence to the rest of that hemisphere, than to the right hemisphere, and these stimuli will therefore be more reliably identified. Under normal hearing conditions, both cochleas receive the same stimuli, and there is no competition between the pathways from the two ears. This might explain why the greater efficiency of the right ear for speech sounds has so far gone undetected. Another reason for this may be that, in normal subjects, both pathways are very efficient, and only material of a certain level of difficulty will permit the detection of a difference between ears.

If the relation suggested here between the identification of verbal stimuli and the hemisphere at which they arrive is correct, one might expect a similar effect with visually presented verbal material. That is, since material in the right field first excites the left hemisphere, it should perhaps be perceived more accurately than the same material in the left field. Unfortunately verbal material presented visually is subject to some very strong influences in the form of reading habits. These tend under some circumstances to make recognition of alphabetical material better in the left visual field (Bryden, 1960; Heron, 1957). Nevertheless, alphabetical material is recognized more efficiently in the right field under a wider variety of conditions (Bryden, 1958; Forgays, 1953; Heron, 1957; Kimura, 1959; Mishkin & Forgays, 1952).

Forgays' developmental data on the greater accuracy of recognition in the right visual field are in agreement with generally held views on the age range in which speech is taken over by one hemisphere. An interesting point is that, under conditions which make the right field more efficient for verbal material, geometric and nonsense forms are recognized equally well in both fields (Bryden, 1960; Heron, 1957; Terrace, 1959). There is of course the possibility that the increased efficiency of the right field for verbal material is also due to reading experience rather than the dominance of one set of pathways. This suggestion has been made by Mishkin and Forgays, and by Heron, and it derives some support from the finding of Orbach (1952) that experience with Hebrew, which is read in a direction opposite to English, tends to make the left field more efficient. This effect is not entirely achieved, however, and Orbach's data, though incomplete, suggest that the right field may in fact be the prepotent one.

A further test of the hypothesis proposed here might be provided by the presentation of non-verbal material in the same way that digits were presented, since with non-verbal material the right ear should be no more efficient than the left. It would also be of interest to discover at what age the right-ear effect first appears, for such information would have direct relevance for the subject of cerebral dominance. Both these problems are now being investigated.

Summary

Patients with epileptogenic foci in various parts of the brain were given an auditory test in which different verbal material was presented to the two ears. One group of subjects had speech represented in the left hemisphere, the other in the right. Stimuli arriving at the ear contralateral to the dominant hemisphere were more efficiently recognized than stimuli arriving at the ipsilateral ear, that is, in the left-dominant group the right ear was more efficient, and in the right-dominant group the left ear was more efficient. This effect was independent of handedness and of the locus of

epileptic discharge. The results are consistent with earlier suggestions that the crossed auditory pathways are stronger than the uncrossed, and that the dominant temporal lobe is more important than the non-dominant in the perception of spoken material.

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