

## DICHOTIC TESTING OF PARTIAL AND COMPLETE SPLIT BRAIN SUBJECTS

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**Abstract**—Four subjects with differing portions of the cerebral commissures sectioned were tested in a consonant vowel dichotic listening task. The two subjects with sections anterior to the splenium and posterior to the first one third of the corpus callosum failed to identify any of the syllables presented to the left ear under dichotic presentation, even under conditions designed to optimize processing and output in favor of that ear. The results were discussed in terms of models of right hemisphere speech processing function and the phenomenon of unilateral neglect with simultaneous presentation of stimuli.

### INTRODUCTION

WHILE there is little disagreement that the neural organization required for spoken language is usually localized in one cerebral hemisphere, the question of the possible lateralization of the centers which process incoming linguistic stimuli is as yet unresolved [1]. At issue is the distinction between a brain in which linguistic processing functions are handled in both hemispheres, and one in which such functions are lateralized to the same extent as the expressive mechanisms.

The dichotic listening test where subjects hear two simultaneous spoken messages, one to each ear, has been instrumental in directly addressing this problem in the auditory sphere [2,3]. The right ear advantage in terms of accuracy of report typically observed with right handed subjects has been interpreted as reflecting the specialization of the left cerebral hemisphere for speech processing as well as the superiority of contralateral over ipsilateral ear-cortex connections [4]. Ear advantage effects in the dichotic listening task have been related to hemispheric specialization for expressive language as determined by sodium amytal testing, and it has been maintained that these data provide support for a unilateral processing/output system [5]. SPRINGER [6, 7] has pointed out, however, that the typical dichotic listening paradigm confounds processing and output functions by requiring the subjects to verbally report the material presented to them. To unconfound these functions Springer employed a modified dichotic task involving a manual response with either the left or right hand and still found a strong right ear advantage. She concluded that the ear asymmetry is at least in part perceptual in origin, yet she noted that one cannot distinguish with available data between a system in which all speech inputs are processed by one hemisphere and a system which has two processors, with one inferior to the other.

The dichotic testing of split brain subjects who have had the connections between the hemispheres sectioned could potentially provide data of great relevance to the issue of unilateral versus bilateral speech processing. MILNER, TAYLOR and SPERRY [8] and SPARKS and GESCHWIND [9] presented split brain subjects with dichotic speech stimuli and found

almost complete extinction of left ear inputs with good report of right ear stimuli. Tests of each ear alone revealed comparable performance for the two ears, suggesting that under dichotic presentation the ipsilateral ear-cortex pathways are suppressed. It is important to note, however, that verbal report was required in these studies so that even if the left ear inputs were processed in the right hemisphere under dichotic presentation, there would be no mechanism for tapping the results of that processing. At the end of their paper, MILNER *et al.* [8] allude to a study in which dichotic pairs of "requests" were presented to split brain subjects who were asked to retrieve the requested items from behind a screen with their left hands. They report that subjects had good success retrieving the left ear input, a finding which suggests that the right hemisphere could process the speech input sufficiently to identify the requested object.

The present study sought to further extend these observations of the performance of the split brain subject in the dichotic listening task. It utilized the dichotic consonant vowel (CV) test devised by SHANKWEILER and STUDDERT-KENNEDY [10] in which single pairwise combinations of syllables are presented on each trial. These stimuli have the advantage of not taxing short term memory in the same way as the dichotic digit task used by MILNER *et al.* [8] and of more directly addressing the speech processing issue. The subjects participating in the study also differed from one another in terms of the extent of commissurotomy, providing an opportunity to determine which portion of the cerebral commissures is responsible for the interhemispheric transfer of speech inputs.

## METHODS

### *Subjects*

Most of the patients tested were operated on by Dr. Donald Wilson of the Dartmouth Medical School in an effort to prevent the interhemispheric spread of epileptic seizures. All cases were right handed males except E.G. who was left handed. Case J.H. underwent complete forebrain commissurotomy at the age of 26. Visual tests of case J.Kn., age 16 at surgery, suggest that parts of the splenium were left intact. Case J.K. had only the anterior commissure and anterior one third of the corpus callosum sectioned.

E.G. is from another series [11]. This 10-year-old boy had the splenium sectioned in the course of removing a tumor from the third ventricle.

### *Stimuli*

The dichotic tape employed in this study was patterned after the one used by SHANKWEILER and STUDDERT-KENNEDY [10]. It consisted of pairs of natural speech CV syllables selected from among the following six: /pa, ta, ka, ba, da, ga/. Each syllable of a pair was recorded on a separate track of magnetic recording tape such that the two syllables had simultaneous onset. A single CV pair composed of two different CV syllables (no syllable was cver paired with itself) constituted a trial. Dichotic presentation was achieved by playing the tape to subjects on a Revox A77 stereo tape recorder through Sharpe 660 headphones. In this way, one syllable of a pair was delivered to one ear while simultaneously the second syllable was presented to the other ear. Each syllable was 300 msec in length and the interpair interval was 6 sec. The computer controlled pulse code modulation system of the Haskins Laboratories was employed in the construction of the tape. Details of the tape construction may be found in SPRINGER [6].

### *Procedure*

Subjects were first exposed to binaural presentation of the six syllables played one at a time in a random order. They were asked to identify each syllable verbally and had no difficulty achieving a criterion of 10 out of 10 correct identifications. Subjects were then shown a response sheet listing the six stop consonants and told that it would be their task to encircle the sound or sounds heard on each trial. A separate sheet was used for each trial. There were three basic conditions per subject: standard dichotic presentation, dichotic presentation with selective attention instructions to attend to the non-dominant ear, and monotic presentation of single syllables. Subjects were told that there were two different stimuli on each trial under the dichotic conditions and they were encouraged to guess the identity of the second syllable if they were not sure. Headphone orientation was counterbalanced across subjects to control for possible differences between tape channels or sides of the headphones.

Where possible, subjects were tested in the dichotic conditions twice, once with the left hand responding and once with the right hand responding. Exigencies of the testing situation, however, precluded the testing of all subjects in each of the possible experimental conditions. The primary consideration was avoiding subject fatigue; accordingly, adjustments in the testing sequence were made for each subject to obtain maximum information from the subject within the limited time for testing. The only exception to this rule was E.G., for whom right hand data are missing because the subject refused to use that hand in any task, claiming he could not use the hand to perform.

## RESULTS

Table 1 summarizes the per cent correct data for each subject under standard dichotic presentation, dichotic presentation with selective attention instructions, and monotic presentation of single syllables.

Table 1.—Per cent correct identification as a function of condition

Subject	Task								
	Standard dichotic			Selective Attention			Monotic		
		LE	RE		LE	RE	LE	RE	
J.H.	(LH)	0	93	(LH)	0	100	(RH)	93	—
	(RH)	7	93	(RH)	7	87			
J.Kn.	(LH)	0	67	(RH)	0	87	(RH)	87	—
	(RH)	13	87						
J.K.	(RH)	37	67	*(RH)	67	53	(RH)	100	75
E.G.	*(LH)	100	17	(LH)	87	13	(LH)	100	67

LE = Left Ear; RE = Right Ear; LH = Left Hand; RH = Right Hand

\*Percentages based on 30 presentations. All others based on 15 presentations.

The extinction of the non-dominant ear under standard dichotic presentation in J.H. is consistent with the findings of MILNER *et al.* [8] and SPARKS and GESCHWIND [9]. J.H. showed good monotic performance in the non-dominant ear, indicating that the ear advantage effect is not peripheral in origin. The data of J.Kn. are very similar to those of J.H. and indicate that a subject with some of the splenium intact is functionally equivalent to a complete split with respect to performance on the dichotic task, confirming that the portion of the callosum important for interhemispheric transfer of speech is anterior to the splenium. J.K. showed superior performance for the right ear yet reported a good number of left ear items, indicating that his section did not involve the area crucial for speech. E.G., the only left hander in the group, had only a portion of the splenium sectioned. He showed good performance in the left ear with chance level performance in the right. While the ear advantage reversal was anticipated for E.G., the right ear extinction was not expected because of the location of the section. This surprising observation may be explained by reference to the monotic data for E.G. given in Table 1 which show a right ear hearing loss relative to the left ear. While supporting data are not available, this finding indicates that a hearing loss in the non-dominant ear may combine with the dominant ear advantage to produce the equivalent of non-dominant ear extinction.

Of great interest is the selective attention performance of J.H. To the extent that the non-dominant hemisphere (the right in this case) can process speech at the level of the basic phonetic units corresponding to phonemes, it was expected that selective attention instructions to attend to the left ear accompanied by non-dominant hand responding would dramatically improve performance in the left ear. The data clearly do not support this prediction.

Table 2. Response frequency as a function of condition

Subject		Standard dichotic									
		Trials with two responses					Trials with one response				
		L & R Corr	L Corr	R Corr	L & R Incorr	Total	L Corr	R Corr	L & R Incorr	Total	
J.H.	(LH)	0	0	0	0	0	0	14	1	15	
	(RH)	0	0	0	0	0	1	14	0	15	
J.Kn.	(LH)	0	0	0	0	0	0	10	5	15	
	(RH)	0	0	0	0	0	2	13	0	15	
J.K.	(RH)	5	9	12	4	30	0	0	0	0	
E.G.	(LH)	5	15	0	0	20	10	0	0	10	
Selective attention											
J.H.	(LH)	0	0	0	0	0	0	15	0	15	
	(RH)	0	0	0	0	0	1	13	1	15	
J.Kn.	(RH)	0	0	0	0	0	0	13	2	15	
J.K.	(RH)	1	6	5	1	13	1	0	1	2	
E.G.	(LH)	1	8	0	0	9	4	1	1	6	

L = Left Ear, R = Right Ear, LH = Left Hand, RH = Right Hand.

Table 2 presents a breakdown of the responses made by each subject in the two dichotic conditions according to whether one or two syllables were reported on a trial. Displayed in this way, the data indicate that non-dominant ear errors were, without exception, errors of omission for J.H. and J.Kn., while for the remaining two subjects they were a mixture of omissions and incorrect identifications. The failure of the left ear-right hemisphere system in J.H. and J.Kn. to even hazard a guess as to the identity of the syllables presented to it must be taken into consideration by any attempt to account for these data.

## DISCUSSION

The present study was designed to investigate the speech processing capabilities of the non-dominant hemisphere using the dichotic listening paradigm. The data indicate that with the appropriate portion of the corpus callosum sectioned, right handed subjects are unable to report any of the CV syllables presented to the left ear even under conditions designed to optimize processing and output opportunities in favor of that ear. Presentation of single syllables to the left ear alone resulted in good identification performance, consistent with a model in which ipsilateral ear-cortex pathways are in some way suppressed during dichotic presentation. Thus the data indicate that the speech inputs having access to the right hemisphere only are not identified. This implicates the region anterior to the splenium and posterior to the first one-third to one-half of the callosum as being crucial in the inter-hemispheric transfer of speech inputs.

In order to interpret these results with respect to limitations on right hemisphere function it is of value to consider the dichotic listening test in the larger context of tasks which involve simultaneous presentation of two stimulus inputs, one to each hemisphere. A number of visual tasks of this type have been employed to determine the degree to which such inputs can be dealt with in parallel in the split brain; that is, they are used to investigate whether the efficiency of one hemisphere is affected by similar processing in the other hemisphere. (Implicit in these studies is the assumption, easily tested in the visual case, that each hemisphere can perform the required task when tested alone.) TENG and SPERRY [12] report striking neglect of the left visual field under conditions of simultaneous presentation of two stimulus inputs composed of letters or digits requiring a manual response.

GAZZANIGA and HILLYARD [13], however, note that other tasks involving simultaneous presentation of material do not produce unilateral neglect [14]. They suggest that lateralized response sets, either manual or verbal, may be necessary but not sufficient for unilateral neglect to occur. Furthermore, they point out that where unilateral neglect occurs it is difficult to ascertain whether the suppressed hemisphere is subjected to an inhibition of its sensory perceptual apparatus or to a decoupling of its processing from motor output.

The dilemma confronting any interpretation of the dichotic listening results in the present paper is that it is difficult to differentiate, in terms of the data, between an explanation based upon unilateral neglect, in this case of the left ear, of the sort observed by TENG and SPERRY [12] and the alternative explanation that the right cerebral hemisphere is incapable of distinguishing among the six CV syllables. The latter possibility is an intriguing one since data from a variety of studies point to the ability of the right hemisphere in the split-brain subject to comprehend speech [15, 16]. The data in support of a right hemisphere speech processor fall into two classes. One strategy has involved binaural stimulus presentation followed by a selection response limited to the right hemisphere through the use of the left hand. Studies of this type are open to the criticism that the major hemisphere also hears and comprehends the auditory material. This, in conjunction with the limited set of objects from which subjects choose in these tasks, leaves open the possibility that the left hemisphere may have aided the right hemisphere by cross cueing mechanisms [16].

A second approach pointing to the existence of a right hemisphere speech processor is the limited work which has demonstrated successful retrieval by the left hand of the left ear member of pairs of dichotically requested objects [8]. The present study involving the dichotic presentation of CV syllables failed to obtain comparable results. The exact nature of the speech stimuli, then, may be crucial in determining whether or not right hemisphere processing is possible. CUTTING [17] has shown that neurologically intact subjects show the largest ear advantage effects for the consonants used in this study, and smaller ear advantages for other types of speech sounds. The right hemisphere processor may be able to extract sufficient information from dichotically presented words to select among a limited set of objects, while failing to adequately process isolated syllables composed of a stop consonant and vowel.

The possibility that the data reflect unilateral neglect of the left ear input, however, rather than an inherent lack of speech processing capacity, receives some support from the finding that all non-dominant ear errors in subjects J.H. and J.Kn. were the result of failures to respond while non-dominant ear errors were composed of both incorrect responses and omissions for subjects J.K. and E.G. The prevalence of omissions rather than incorrect identifications was observed by TENG and SPERRY [12] for responses to left visual items under bilateral presentation conditions. The seemingly analogous findings for the left ear observed under dichotic presentation suggest that the two phenomena may be reflective of a common mechanism which is independent of the capacity of the right hemisphere to handle stimuli when tested alone.

While the data in the present study do not provide exceptionally compelling support for either of the two main interpretations discussed here, they do serve to emphasize the complexity of the problem of determining the speech processing capacities of the right cerebral hemisphere. Further complicating the interpretation of these data is the observation that subjects J.H. and J.Kn. could sometimes verbally report material presented to the left ear under dichotic presentation when the stimuli were pairs of animal names such as 'doggy/horsey' and 'lion/fishy' [19]. This preliminary observation suggests that very close

attention will have to be paid to the nature of the speech stimuli in terms of both phonetic and semantic considerations when drawing conclusions concerning hemispheric functioning.

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**Résumé**—On a soumis à une épreuve dichotique consonnes-voyelles, quatre sujets ayant subi des sections de différentes portions des commissures cérébrales. Les deux sujets avec section antérieure au splénium et postérieure au premier tiers du corps calleux, avaient un échec total dans l'identification des syllabes adressées à l'oreille gauche en présentation dichotique, et ceci même sous des conditions créées pour améliorer le traitement et la sortie en faveur de cette oreille.

On discute ces résultats à partir de modèles de fonctions du traitement de la parole par l'hémisphère droit, en tenant compte du phénomène de négligence unilatérale lors de la présentation simultanée des stimuli.

**Zusammenfassung**—Vier Personen mit Sektion unterschiedlicher Gebiete der zerebralen Kommissuren wurden in einer dichotischen Konsonant-Vokal-Aufgabe getestet. Die beiden Personen mit Sektion vor dem Splenium und hinter dem ersten Drittel des Corpus callosum konnten keine der dem linken Ohr dichotisch präsentierten Silben identifizieren, nicht einmal unter Bedingungen, die dazu bestimmt waren, die Verarbeitung und den Output dieses Ohres zu verbessern. Die Ergebnisse werden diskutiert im Hinblick auf Modelle der Funktionen der Sprachverarbeitung der rechten Hemisphäre, wobei dem Phänomen der einseitigen Vernachlässigung bei simultaner Präsentation der Stimuli Rechnung getragen wird.