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DICHOTIC STUDIES II

Two Questions

The present issue is the second of two special issues of *Brain and Language* given over to dichotic studies. While the first (*Brain and Language*, 1, 4) was largely concerned with analytic studies of ear advantages in the processing of acoustic, phonetic and syntactic aspects of spoken language, the second is concerned with individual differences in ear advantages for various language tasks, and with their relations to other behaviors. Cutting across both issues are two related questions.

The first question concerns the mechanism of perceptual asymmetries. Most investigators have accepted Kimura's (1961a,b) proposal that these asymmetries reflect the asymmetric functions of the cerebral hemispheres. There is, in fact, so much evidence in favor of this hypothesis that it would be difficult to do otherwise. However, not everyone has accepted her structural account of each input's privileged access to its contralateral hemisphere. Kimura (1961a,b, 1967) attributed this privileged access to functional prepotency of contralateral over ipsilateral ear-to-hemisphere connections. Contralateral prepotency rested on the greater number of contralateral than ipsilateral connections, combined with afferent and perhaps central occlusion of the ipsilateral connections during dichotic competition. Occlusion is evidently not essential, since a sensitive measure of lateralization, such as reaction time, may reveal monaural ear advantages even on quite simple tasks (e.g., Haydon & Spellacy, 1973; Fry, 1974; Morais & Darwin, 1974). However, there is strong evidence from work on split-brain patients that dichotic competition does induce occlusion. Milner, Taylor and Sperry (1968), Sparks and Geschwind (1968) and, more recently, Zaidel (1973, 1974), have demonstrated that, while these subjects perform equally with left and right ears on monaural identification of digits or nonsense syllables, their dichotic performance reveals a massive, often total, left-ear loss. Moreover, Zaidel (1974) has evidence pinpointing the locus of occlusion as central rather than subcortical. These investigators interpreted their results to make explicit what had been implicit in Kimura's original model, namely, that when normal right-handed subjects attempt to recognize the left-ear input of a dichotically-presented pair, they do so from a "degraded" signal that has traversed an indirect path from left ear to right hemisphere, and from right hemisphere to left hemisphere across the corpus callosum.

Central to this account is the assumption of total asymmetry of perceptual function. Variations in ear advantages across phonetic classes (stop consonants, glides, vowels) (Shankweiler & Studdert-Kennedy, 1967; Studdert-Kennedy & Shankweiler, 1970; Cutting, 1974b) would not, according to this model, reflect variations in the degree to which the two hemispheres are engaged in their processing, but variations in the degree to which the phonetic classes are liable to transcallosal degradation. Furthermore, as the model would predict, these variations can be eliminated and the vowels induced to yield a right ear advantage, if their relative clarity is reduced by presenting them at lower signal-to-noise ratios (Weiss & House, 1973), or as members of an acoustically confusable stimulus set (Godfrey, 1974; cf. Darwin & Baddeley, 1974). Similarly, variations in ear advantages across individuals would not reflect variations in degree of hemispheric asymmetry, but variations in degree of contralateral prepotency (Shankweiler & Studdert-Kennedy, this issue). Again, as the model would predict, contralateral prepotency can be eliminated, if the relative clarity of the right-ear input is reduced by presenting it at a lower signal-to-noise ratio or appropriately filtered (Cullen *et al.*, 1974). Furthermore, individual-ear advantages for signals of matched intensity are highly correlated with the amount by which right-ear signal intensity must be reduced in order to eliminate its advantage (Brady-Wood & Shankweiler, 1974). In short, Kimura's model has been widely accepted, and makes sense of a good deal of data.

Nonetheless, two recent studies report results that are incompatible with a simple wiring account of ear advantages in terms of ear-to-hemisphere connections. First, Goldstein and Lackner (1974) have demonstrated that laterality effects may be influenced by subjects' perceived spatial orientations: the normal right ear advantage for consonant–vowel syllables is reduced, if subjects wear prisms that displace their visual environments to the left, increased if the prisms displace the environments to the right. Second, Morais and Bertelson (1973) have shown that the strongest perceptual advantage accrues to sounds originating in the median plane, the direction of gaze: Although subjects display a significant right-speaker advantage for competing CV syllables presented over left and right loudspeakers, they show a significant front-speaker advantage, if the syllables are presented over either front and left or front and right loudspeakers. Both these studies implicate localization mechanisms, and suggest that the routing of signals to hemispheres rests, at least in part, on some low-level decision as to the spatial origins of the signals. Evidently, whatever factors determine perceived localization (including, presumably, relative intensity, temporal relations between incoming signals, attention and ear-to-hemisphere connections) will determine the proportion of incoming information that is routed to one or another of the hemispheres. The relative degrees of contralateral/ipsilateral ear-to-hemisphere connections would then have their effect on ear advantages indirectly, as by-products of their roles in auditory localization (cf. Haggard, in press).

These studies are, in fact, more readily compatible with an account of lateral asymmetries in terms of hemispheric specialization and selective attention, or expectancy. Kinsbourne (1970, 1973) first formulated this position, and has elaborated it largely on the basis of visual field studies. He takes as his starting point the fact that each hemisphere serves the contralateral half of space. He proposes that activation of one hemisphere turns attention toward the opposite side, and, at the same time, by the principle of reciprocal innervation, inhibits activation of the other hemisphere. He has demonstrated experimentally, by asking questions that call for either verbal (left hemisphere) or spatial (right hemisphere) responses, that subjects orient their gazes away from the midline in a direction contralateral to the putatively activated hemisphere. He has demonstrated, further, that subjects, called upon to retain a list of six words in memory (left-hemisphere activation), while carrying out a tachistoscopic detection or recognition task, display a right field advantage, where they had previously displayed none, while subjects called upon to rehearse a melody (right-hemisphere activation) display a left field advantage. Kimura herself (Kimura and Durnford, 1974) has shown that subjects display a right-field advantage for recognition of tachistoscopically presented geometric figures, if they have just performed a similar task for letters, but no advantage, if they do the tasks in reverse order. From here it is a short step for Kinsbourne (1970, 1973) to propose (without necessarily denying callosal transmission of the ipsilateral signal) that, given hemispheric specialization as a basis, lateral asymmetries may arise from attentional set induced by the nature of the task rather than from structurally determined contralateral prepotency and transcallosal degradation.

There is, in fact, a lot of evidence that involuntary attention plays a role in determining ear advantages. For example, subjects have difficulty in reversing the "natural" attention of the left hemisphere during a verbal shadowing task: Information from the unattended right ear is more likely to intrude than information from the unattended left ear (Treisman & Geffen, 1968). Similar results were reported by Kirstein and Shankweiler (1969) for subjects taking a standard consonant–vowel syllable test under conditions of directed attention. Furthermore, several studies have shown that dichotically presented vowels, for which a null ear advantage is typical, will yield a right-ear advantage if they are presented in an appropriately biassing experimental context (Spellacy & Blumstein, 1970; Haggard, 1971; Darwin, 1971; Tsunoda, this issue). In short, an attentional model can account for a variety of data that is not readily accommodated by a structural model. But, as Kinsbourne (1973, p. 252) has remarked, what is needed to discriminate between them is an experiment in which materials known to yield a left-ear advantage (e.g., melodies) are mixed with materials known to yield a right-ear advantage (e.g., CV syllables) in the same test. Kimura's model would then predict the usual ear advantages, Kinsbourne's their reduction.

Let us turn now to the second broad question underlying several of the papers in these special issues: the nature and extent of the language hemisphere's peculiar functions. Here, Kinsbourne's model has the advantage that it can accommodate linguistic functions for which asymmetry is partial as readily as those for which asymmetry is total, since the model postulates that the minor hemisphere may be inert due either to total incapacity or to inhibition by the dominant hemisphere. This is a virtue of the model, since the evidence to date suggests that normal language function entails various processes, some of which are entirely peculiar to the language hemisphere, others of which may, under certain circumstances, be carried out by either hemisphere.

Among the grounds for this statement are the results of work with split-brain patients. The right hemispheres of such patients, although largely mute, have been shown to be capable of considerable verbal comprehension (Sperry & Gazzaniga, 1967; Gazzaniga & Sperry, 1967; Gazzaniga, 1970), including that of complex syntactic and semantic structures (Zaidel, 1973). There are thus important linguistic functions which both hemispheres are equipped to perform. At the same time, as we have seen, the right hemispheres of split-brain patients are almost totally incapable of extracting phonetic information from the left-ear (right hemisphere) member of dichotically presented digits (Milner, Taylor & Sperry, 1968; Sparks & Geschwind, 1968) or nonsense syllables (Zaidel, 1974). It was in response to this paradox that Studdert-Kennedy and Shankweiler (1970, p. 590) proposed that, for the split-brain patient

> . . . right hemisphere . . . comprehension rested on auditory analysis which, by repeated association with the outcome of subsequent linguistic processing, had come to control simple discriminative responses.

Essentially the same conclusion has been reached by Zaidel (1973, 1974) on the basis of extensive dichotic studies, and by Levy (1974) on the basis of a series of visual field studies, with split brain patients. Levy, for example, showed that while the right hemispheres of these patients were able to name pictures of simple, familiar objects (rose, eye, bee), they were unable to recognize that the names of these pictured objects rhymed with "toes," "pie" and "key." In other words, the right hemispheres were able to recognize semantic, but not phonetic, rela tions. From this and other studies Levy (1974) has concluded that

> . . . there is no evidence whatsoever that the right hemisphere can analyze a spoken input into its phonetic components . . . (p. 161).

Rather,

> . . . it seems probable that the right hemisphere can decode written or spoken input by having integrated graphologies and phonologies which are tied to their appropriate meanings . . . and merely utilizes its few whole phonologies to translate input to meaning and meaning to output (Levy, 1974, p. 161).

If this is so, then we may further conclude, with Studdert-Kennedy and Shankweiler (1970, p. 590), that

> to the dominant hemisphere [belongs] that portion of the perceptual process which is truly linguistic: the separation and sorting of a complex of auditory parameters into phonological features.

There is, to be sure, scattered evidence that specialization of the language hemisphere may extend as far down into the perceptual process as the detection of characteristic acoustic properties, including temporal order (e.g. Halperin, Nachshon & Carmon, 1973; Papcun, Krashen, Terbeek, Remington & Harshman, 1974; Cutting, 1974a,b). However, acoustic analysis does not proceed in isolation. Biological selection of acoustic properties for specialized processing may well have been guided by the function of those properties in determining phonetic structure (cf. Studdert-Kennedy, in press). And, in fact, the mere presence of apt acoustic properties in a speech signal is not sufficient to engage the language hemisphere: For example, recognition of the emotional tone of an utterance, despite its phonetic carrier, engages the right rather than the left hemisphere (Haggard & Parkinson, 1971). Thus, whatever specialized semanto-syntactic processes may subsequently be involved (Zurif, 1974), initial activation of the language hemisphere by speech seems to entail analysis of the signal into its segmental phonetic components. Wood's (1975) elegant work with electroencephalography has lent strong support to this conclusion.

Certainly, phonological analysis may be no more than an instance of a general left hemisphere cognitive capacity for detailed temporal analysis and abstraction, as compared with that of the right hemisphere for spatial analysis and holistic figure recognition (Bever & Chiarello, 1974; Levy, 1974). Certainly, too, phonological analysis may not be the sole linguistic process to be grounded in such a general capacity: As Zurif (1974) has pointed out, we are sorely in need of well-designed dichotic studies to tease out and identify the semanto-syntactic processes of language perception. Nonetheless, it may be salutary to recall that the single most distinctive property of language as a medium of communication is its construction of meaning from a foundation of meaningless elements (Hockett, 1958; cf. Kimura, in press). Perhaps research will most profitably proceed from the bottom up.

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