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# Hemisphericity: A Critical Review

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Hemisphericity refers to the idea that people may rely on a preferred mode of cognitive processing, which is linked to activity on the part of the left or right cerebral hemispheres. Four methods have been used in hemisphericity research: lateral eye-movements, electrophysiological measures, questionnaires and cognitive tests. It is demonstrated that none has been properly validated with respect to the purposes for which they are employed in studies of hemisphericity. It is argued that the idea of hemisphericity lacks adequate foundation and that, because of the assumptions implicit in the idea of hemisphericity, it will never be possible to provide such a foundation. The idea is a misleading one which should be abandoned.

## INTRODUCTION

Over the last decade, following the upsurge of studies of specialisation of the cerebral hemispheres, there has been increasing use of the concept of *hemisphericity*. Although the term tends to be used rather differently by different writers, it generally indicates the idea that each individual may tend to rely on a preferred mode of cognitive processing which in turn implies the predominant activity of either the left or the right cerebral hemisphere.

The characteristic of hemisphericity has been linked to a number of aspects of personality, reasoning and thought, as well as to abnormal states. Much of the work has concentrated on educational and cognitive-developmental aspects (Bogen, 1977; Gallagher & Joseph, 1982; Klein, 1980;

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Oexle & Zenhausern, 1981; Olson, 1979; Prince, 1978; Samples 1975; Wheatley, Mitchel, Frankland & Craft, 1978; Zenhausern & Nickel, 1979), including some studies of college-level performance (Bracken, Ledford & McCallum, 1979; Wiet, 1981; Wiet & Goldstein, 1981). Allied to this have been studies of creativity and problem solving (Garrett, 1976; Konicek, 1975; Rekdal, 1979; Torrance, 1982; West, 1975: Wheatley, 1977), and an interest in poetry and mysticism (Cashford, 1979), prayer (McCandless, 1980), and the origins of human consciousness (Jaynes, 1976). Psychiatric states have been discussed in this context (Galin, 1974; Gruzelier, 1981), as well as more general aspects of personality (Hirschman, 1983; LeBoeuf, 1982; Smokler & Shevrin, 1979), and individual psychodynamics (Rossi, 1977). Hemisphericity has therefore been considered to be relevant in examining a variety of psychological and social issues in education, art, architecture, religion and personal life-style. The subject is, of course, also to be found in recent general texts on neuropsychology (Beaumont, 1983a; Springer & Deutsch, 1981).

That there are lateral differences between the cerebral hemispheres in the organisation of human performance is not in doubt (Beaumont, 1982a; Bradshaw & Nettleton, 1981, 1983; Dimond & Beaumont, 1974; Kinsbourne, 1978). That the research on hemisphericity has brought to light a number of interesting phenomena (see, for instance, the studies reported by Gordon, 1980; Gordon, Frooman & Lavie, 1982) is also not in dispute. However, it seems worth asking just how clear the link is between these phenomena and lateral specialisation of the brain. Is the interpretation of these findings in terms of brain organisation a valid one, or do they simply represent what has been termed "neuromythology" or "neurophrenology?"

Recent reviews, which have included a passing reference to hemisphericity, have, in general, questioned the value of the idea. Bradshaw and Nettleton (1981, p. 63) conclude that "it is misleading to use cognitive mode to characterize people as being dominated by one hemisphere or another." Similarly, Corballis (1980, p. 288) refers to the "simplistic notion that there are contrasting styles identified with the two cerebral hemispheres" and concludes that "the notion of hemisphericity has . . . enjoyed little empirical support." Neither of these reviews, however, examines the evidence closely or presents a detailed analysis on which such conclusions are based. Hardyck and Haapanen (1979) review some of the relevant neuropsychological evidence in more detail, but specifically within the context of educational applications, and conclude that there is no scientific basis for any proposals to selectively educate the left or right halves of the brain. Although they, rather surprisingly, recommend procedures for the separate development of left and right hemisphere skills, McCallum and Glynn (1979) are highly critical of the experimental bases upon which such ideas are founded. These reviews all suggest that the foundations of hemisphericity research deserve more careful scrutiny.

The purpose of the present review is to examine the empirical and

theoretical bases of hemisphericity research. Following a brief historical introduction, the relevant empirical and theoretical issues are examined in turn. It should perhaps be pointed out that although the idea of hemisphericity has been supported by some prominent neuropsychologists, much (but not all) of the empirical work that it has inspired has been of poor scientific quality. In reviewing the large number of available studies we have sought to give most attention to those that are the most substantial or most often referred to in the literature, but we have also included reference to a number of less important papers in order to demonstrate the full range of the types of study that have been carried out.

## THE ORIGINS OF HEMISPHERICITY

The idea that different mental states may be associated with the activity of different cerebral hemispheres is not new. It was, for instance, put forward by Bruce (1895) to account for a case of dual personality. Bruce's patient, a Welshman, alternated between two mental states. In one he was described as left-handed, Welsh-speaking, apathetic, and demented. In the other state he was described as right-handed, English speaking, manic destructive, and thievish. Bruce commented:

> ... it would appear than in this case, the cerebral hemispheres are capable of individual mental action ... the patient living two separate existences during the stages through which he passes ... (Bruce, 1895, p. 64)

The origins of the term "hemisphericity" are, however, to be found in the paper of Bogen, DeZure, TenHouten and Marsh (1972). In arguing for their "neurosociologic" theory they present evidence for "differential hemispheric participation in different circumstances" which is mostly drawn from electrophysiological, reaction time, and lateral eye-movement studies. Their main intention is to establish that if hemisphericity exists it can be associated with differential cultural experience. Their measure of relative hemisphere involvement is the A/P (Appositional/Propositional) ratio calculated from the results of the Similarities test taken from the Wechsler Adult Intelligence Scale (WAIS) and the Street Figure Completion Test. The selection of these two tests is largely on the basis of evidence from the effects of lateralised clinical lesions. It is also considered in the case of the Similarities test that, as the right hemisphere has very limited capacity for verbal expression in commissurotomy patients, "any achievement on this test following cerebral commissurotomy can therefore be confidently assigned to the left hemisphere" (Bogen et al, 1972, p. 53). Recent discussions of the effects of commissurotomy (Beaumont 1981, 1982a; Coltheart, 1980; Sidtis, Volpe, Wilson, Rayport & Gazzaniga, 1981; Whitaker & Ojemann, 1977) might diminish confidence in this assignment, as the linguistic ability of the right hemisphere of split-brain patients has become increasingly apparent (but see also Gazzaniga, 1983a, b; Levy, 1983; Zaidel, 1983).

Bogen et al (1972) seek to establish the validity of their hemisphericity index by measuring the A/P ratio not only in a number of different ethnic samples, but also in a number of commissurotomy patients. They were able to show that not only were there differences between the ethnic groups, with urban whites showing a bias towards a propositional mode while blacks and rural whites and Hopis were more appositional in performance, but that the commissurotomy patients also showed lower A/P ratios (more propositional). The results of these patients were significantly more propositional than any of the normal groups, although the actual ratios which they exhibited were well within the range of the distribution of the urban white ratios. This was interpreted as evidence that ethnic groups can be meaningfully classified in terms of the differential availability of propositional and appositional capacities. There has been some criticism by Zook and Dwyer (1976) of the statistical analysis of the results of the normal groups, and a reply by TenHouten, Thompson and Walter (1976), which involved some re-analysis, but neither paper recommends any fundamental change in the assumptions which underlie the use of the A/P ratio.

Neurosociologic theory has been discussed and extended in a number of publications (Hepburn, 1977; Kaplan, 1977; Paredes, 1977; Paredes & Hepburn, 1976; TenHouten, 1976, 1977; Thompson & Bogen, 1976). These have almost exclusively centred around discussions of anthropological data and the behaviour patterns to be observed in different cultures. TenHouten's (1976) classification of the areas of evidence into *performance* on lateralised tests, *cognitive style*, and *use laterality* (referring to electroencephalographic evidence) was a useful contribution upon which some later discussion has been based, but very little new empirical neuropsychological evidence was introduced during the course of this debate.

## STUDIES OF HEMISPHERICITY

Despite TenHouten's (1976) classification, our view is that the main line of investigation of hemisphericity, at least in so far as it has examined psychological variables, has relied upon four different ways of assessing hemisphericity: lateral eye-movements; electrophysiological measures; questionnaires; cognitive tests. These are relatively independent forms of reference for each investigatory paradigm and the validity of each can be considered in turn, followed by an examination of studies that have sought external validation of the hemisphericity measures employed.

### Lateral Eye Movements

Conjugate lateral eye movements (LEMs) have for some time been held to be associated with laterality of cerebral function. The model, in brief, is that lateral deviation of direction of gaze during thought indicates activation of

the contralateral cerebral hemisphere. The way in which this phenomenon has been employed can be illustrated by a study which provides a suitable example. Sandel and Alcorn (1980), basing their method on a number of reports of LEM research in normal groups (and all reviewed by Ehrlichman & Weinberger 1978), calculated hemisphericity scores directly from the number of left and right LEMs following confrontation with a set of "verbal" and "spatial" questions employed in previous research. Basically, if 70% or more of the movements were in a given direction, then an assignment to the left or right hemisphericity group was made, other subjects being classified as bilateral, although the actual formula used provided mathematical compensation for no change in gaze. They then proceeded to examine the hemisphericity scores, so determined, of four groups of psychiatric patients.

The point about this study, and a number of others (Bruce, Herman & Stern, 1982; LaTorre, Gossman & Piper, 1976; Newlin, 1981; Ray, Georgiou & Ravizza, 1979), is that it derives its validity directly from the research on LEMs. This research has already been expertly reviewed by Ehrlichman and Weinberger (1978). They come to the clear conclusion, on the basis of a consideration of quite extensive evidence, that while LEMs can be a reliable and consistent phenomenon (with some qualification), they are not necessarily related to hemisphere asymmetry. In fact, they go further and state that "variables that ought to correlate with LEM patterns if the latter are indicators of hemisphericity tend not to, and variables that do correlate with LEM patterns are only tangentially related to hemispheric asymmetry" (p. 1096). In addition, they point to the lack of any direct evidence to link imagery or creativity with the right hemisphere, and conclude that while there might be some relationship between certain aspects of laterality and LEMs, the findings are too weak to cite as evidence for or against a hemisphere asymmetry model of lateral eye-movements. It is clear that Ehrlichman and Weinberger consider that there is little justification for linking LEM patterns with hemisphericity.

Several studies have appeared since the publication of Ehrlichman and Weinberger's review, but these have not produced evidence which would radically alter their conclusions. Berg and Harris (1980) and Takeda and Yoshimura (1979) both failed to find stable effects of task upon LEMs. Säring and Von Cramon (1980) presented the questions to subjects in a darkened room, but again found no influence of question type upon first eye movement following the question. Richardson (1978) has also argued against the validity of LEMs as indicators of cerebral activity.

Some positive results have, however, also appeared. Evoked potentials to checkerboard stimuli were studied in left- and right-lookers by Shevrin, Smokler and Kooi (1980), and they found an occipital P90 component on the side contralateral to the preferred direction of gaze deviation. Results of this kind are, however, hard to interpret, especially in terms of cognitive function, since the tasks often do not involve significant cognitive activity

(Rugg, 1982). Tucker and Suib (1978) also studied criterion groups of left- and right-moving subjects, using cognitive tests drawn from the Wechsler Adult Intelligence Scale. Left-movers were found to have higher scores on the Block Design and Object Assembly subtests, and right-movers on the Information and Vocabulary subtests. The first two subtests can be seen as associated with right hemisphere function and the last two with left hemisphere function, supporting the cerebral lateralisation model of LEMs. Whether this association between WAIS subtests and hemisphere lateralisation is valid or not will also be examined below. Huang and Byrne (1978) showed that narrow categorisers on Pettigrew's Category Width Scale made significantly more leftward LEMs than did broad categorisers (narrow categorisers are better at tasks demanding detailed or analytic processing; broad categorisers are better when a more integrated or holistic strategy is demanded). The evidence does, therefore, provide some weak support for LEMs as indicators of hemisphericity, but it must be set against the body of evidence which casts doubt on both the reliability and validity of LEMs employed in this context.

Most studies of hemisphericity using the LEM measure have been simply content to refer to the studies reviewed by Ehrlichman and Weinberger, or the aforementioned additional references, as in the Sandel and Alcorn (1980) study. Ray, Georgiou and Ravizza (1979) merely cite the study of Tucker and Suib (1978) in support of using LEMs in conjunction with two spatial tasks: a Paper Formboard test and a horizontality judgement task. They found performance on the two spatial tests to be correlated for all males but only for left-lookers among females. They conclude that "hemispheric preference indexed by eye movement was less related to spatial ability in the men than in the women" (p. 456). This, of course, is not the only inference which can be drawn from this pattern of results, and insufficient information is provided by the design or given in the paper to judge whether it is in fact the correct conclusion.

Newlin (1981) acknowledges the problems raised by Ehrlichman and Weinberger, and seems to accept their conclusions, but adds the evidence of Shevrin et al (1980) and also a study by Gur and Reivich (1980) in support of using LEMs to assess hemisphericity. The weak support provided by Shevrin et al has already been noted. The Gur and Reivich study involved regional cerebral blood flow measurement. They found, in common with others, that "verbal" and "nonverbal" tasks can be associated with differential increases in blood flow in the left and right hemispheres respectively. They also showed that left- and right-movers showed different patterns of lateral blood flow. However, these were independent studies, and they did not directly show that subjects with different eye-movement patterns had different patterns of blood flow asymmetry under cognitive task involvement. Without a direct study of this kind, the inference from these blood flow studies is distant, and the support which they can give to the use of LEMs to measure hemisphericity tenuous.

Dawson, Tucker and Swenson (1981) factor-analysed a large battery of tests and examined the extracted factors in the light of lateral eye movement indices. They found that of the four main factors which were extracted, none was correlated with the hemisphericity indices derived from LEMs.

The conclusion must be that at present there is insufficient evidence to justify using LEMs as an index of hemisphericity. It is not sufficient for studies to merely cite selected references from the eye movement literature in support of their, at best weak, association with cerebral lateralisation, without any independent validation that the LEMs do in fact reflect selective activation of the left and right hemispheres.

## Electrophysiological Measures

Electrophysiological studies can be divided into studies of the EEG and studies of averaged evoked potentials: EEG studies have been the more commonly used in hemisphericity research. The evidence from EEG research is difficult to evaluate because, this being one of the most technically demanding areas within psychology, much of the debate revolves around methodological issues. These include the positioning of electrodes and reference electrodes, recording parameters, data analysis (including the appropriate use of ratio scores), and the nature of the cognitive task employed. Recent reviews of whether there are lateralised effects of cognitive task to be found in the on-going EEG all agree that as yet there has been no conclusive demonstration of such effects (Beaumont, 1982b; Donchin, Kutas & McCarthy, 1977; Donchin, McCarthy & Kutas, 1977). The same conclusion seems to hold for evoked potential studies (Rugg, 1982). Some writers are willing to accept that despite the methodological problems inherent in all the studies, there is a general trend in the literature towards the existence of lateralised EEG components. No study, however, has been able to show unequivocally that this is the case, although the study of Furst (1976), in which he showed a correlation between EEG asymmetry and performance on a series of visuo-spatial tasks, would seem to be one of the more impressive.

The evidence usually cited by hemisphericity studies is that presented by Galin and Ornstein (1972, 1975), in which left:right alpha ratios were reported which varied with various cognitive tasks. These tasks included some in which purely mental performance was required (although not strictly "imagery" tasks as claimed by Zenhausern, 1978). There are a number of difficulties with this report, not least being the use of ratios to express lateral asymmetries. These difficulties have been extensively discussed by Gevins et al (1979a,b), who present a very powerful case, including empirical evidence, to suggest that the Galin and Ornstein findings are artifactual, resulting from the contamination of motor elements in response, procedural factors and the method of analysis.

It might also be noted that in a later study by Ornstein and Galin (1976)

in which differential hemispheric asymmetries were searched for in different occupational groups, such differences were not in fact found. This seems just the kind of effect which would be predicted by hemisphericity theories, and it should be worrying that it could not be demonstrated.

The electroencephalographic research is too technical to be pursued further here. There may well be laterality effects to be found in the EEG, but no experimental paradigm has yet been established which would enable a reliable index of lateral hemisphere function to be derived from EEG recordings, although two recent studies have showed a reasonable degree of test-retest reliability and internal consistency in the results (Amochaev & Salamy, 1979; Ehrlichman & Wiener, 1979).

Much the same conclusions hold for evoked potential studies (see Rugg, 1982, for a review and critical discussion), though these have not yet been used much in hemisphericity research.

Finally, it should be noted that the existence of both anatomical asymmetries in the cerebral cortex and considerable differences between the brains of different individuals (LeMay & Geschwind, 1978) implies that electrodes placed at homologous points on the scalp may not be above homologous points on the cerebral cortex. This problem is worse in some cerebral regions than others, and for certain kinds of study, but it can invalidate the basic strategy of electrophysiological investigation of hemisphere specialisation.

## Questionnaires

The use of questionnaires has been particularly popular in hemisphericity research, no doubt because of their ease of administration. Of the available questionnaires, the Your Style of Learning and Thinking questionnaire (SOLAT or YSLT) has been the most widely used (Torrance, 1982; Torrance & Reynolds, 1980; Torrance, Reynolds, Riegel & Ball, 1977). This questionnaire contains items enquiring about the subject's preference for various kinds of cognitive activity. Each item provides two contrasted responses and a third neutral response among the three multiple choices. Reference to the manual for the test shows that the validation of this questionnaire is almost entirely by reference to a set of creativity tests. The legitimacy of this approach is founded on Torrance and Reynolds' belief that "there is considerable evidence to suggest that the essence of creativity is a specialized function of the right cerebral hemisphere" (Torrance & Reynolds, 1980, p. 2). In view of this it is not surprising that other validation studies (Torrance & Mourad, 1978, 1979) have found a correlation with other creativity measures, or with "Learning Readiness" scales which share a considerable amount of content with both the SOLAT questionnaire and other creativity scales.

Reynolds and Torrance (1978) have also reported effects of training on their hemisphericity index, but it should be noted that the nature of the questionnaire means that this is entirely based upon self-report, and that the

training procedures incorporated specific discussion of the topics addressed by the questions in SOLAT. There is therefore considerable scope for confounding the results of this investigation.

The only independent study using the questionnaire approach comes from Kaltsounis (1979). He examined the validity of the SOLAT, but only with reference to the Torrance tests of creativitity, and found right-dominant subjects (those having a score above the median on the SOLAT) to have higher ratings for fluency, flexibility, originality, and elaboration on the Torrance scales.

Zenhausern (1978) has developed an instrument called the Style of Thinking questionnaire, based upon the literature concerning LEMs and EEG measures. However, Zenhausern and Repetti (cited in Zenhausern & Gebhardt (1979)), report 70% agreement between this questionnaire and the SOLAT in classifying subjects as left- or right-dominant. Some correlations between this questionnaire and clinical personality scales have been reported by Dunivin and Zenhausern (1981).

The validity of this approach to hemisphericity at present therefore largely boils down to the link between lateral cerebral function and creativity. Katz (1978) has reviewed this question and concluded that "direct evidence using hemisphericity measures is not conclusive" (p. 254), describing the links between creativity, the right hemisphere and various other processes as "at present mere speculations" (p. 262). There is certainly no evidence in the clinical neuropsychological literature, in the experimental studies of divided visual field and dichotic stimulation, or in the commissurotomy research, which would indicate a definite association between the right hemisphere and creativity, as reference to the reviews cited earlier will show. In fact Zangwill (1976) remarks that it is often patients with lesions of the *left* frontal lobe who score poorly on tests of divergent thinking. In the light of this, any index of hemisphericity validated with reference to creativity measures alone must be highly suspect. There is therefore no reason to believe that currently available questionnaires can assess the differential contribution of the cerebral hemispheres to cognitive function.

## Cognitive Tests

A number of investigations of hemisphericity have been based upon cognitive tests, deriving their validity from findings with patients who have focal cortical lesions. The logic is that if test performance can be associated, from clinical evidence, with the function of one of the hemispheres, then it can in turn form part of an index of hemisphericity.

This seems a sensible research strategy, if only it were to be rigorously applied. What has tended to happen, however, has been that investigators have not selected tests which are well validated in clinical research, but have taken the general neuropsychological finding that, very crudely, "verbal" tests are associated with the left hemisphere and "nonverbal" tests with the

right hemisphere. Tests which are assumed to measure generally "verbal" or "nonverbal" functions have then been used to assess hemisphericity, without *direct* clinical validation.

Martindale (1978) provides an example of this approach. He contrasted the scores of Jews, compared to Catholics and Protestants, on certain Verbal and Performance subtests of the WAIS, arguing for differential hemispheric organisation on this basis. This study has been extensively criticised by Levinson (1980). Similarly, Klein and Armitage (1979) used paper and pencil tests, which they had selected as being typical verbal or spatial matching tasks, to study temporal variation in human performance. They found 90–100 minute oscillating cycles in the superiority of verbal or spatial function, and attributed these to alternating activation of the hemispheres.

Unfortunately, it is important to note that even within the range of pathological performance, it is not so simple to identify the laterality of a lesion from general cognitive tests. The idea that a simple comparison of Verbal and Performance subtests on, say, the WAIS could indicate lateralisation has long been discounted (Berent, 1981, Golden, 1981; De Renzi, 1982). Such a discrimination can only be made with specialised tests, designed so that the measure of performance derives from a discrete functional ability, and is not arrived at by means of an aggregate score comprising several different abilities.

There are however, indications that this kind of approach, if more carefully applied, could be of value. Bentin and Gordon (1979) have devised a "Cognitive Laterality Quotient" (CLQ) based upon a battery of "left" and "right hemisphere" tests and characterised as an A/P ratio. Although still leading to an aggregate score, their individual tasks have been fairly carefully derived from the clinical literature and, more importantly, they present validation data from a group of neurological patients. The CLQ correctly identified the laterality of lesion in 93% of 30 cases. This battery may take some time to administer, and demands some specialised apparatus, but could develop into a useful clinical instrument, which might also be used *with* normals. Unfortunately, in further studies by Gordon (1980), Gordon, Frooman and Lavie (1982), and Gordon, Silverberg-Shalev and Czernilas (1982) the actual tests used in determining the CLQ were different to those in the original CLQ battery, and different to each other. Some of the original CLQ tests were dropped and replaced with new tests introduced in each study. Thus, although the approach pursued by Gordon and his co-workers remains attractive, it will be necessary for a more stable test battery to be developed and adopted before any firm conclusions as to its usefulness can be reached.

A further cognitive measure used in hemisphericity research is the field dependence test, either in the form of the Rod and Frame Test, in which subjects attempt to set a rod to true vertical while ignoring the presence of a tilted frame around it, or the Embedded Figures Test in which subjects are asked to find a stimulus which is embedded in a more complex stimulus

display (see O'Connor & Shaw, 1978; Zoccolotti & Oltman, 1978; for reviews). In each case the suggestion is that psychological differentiation is associated with neural differentiation. This might be expressed, for example, by field-independent subjects exhibiting appropriate lateral asymmetries (a right visual field advantage for letter discrimination; left visual field advantage for face discrimination) which are not to be observed in field dependent subjects.

Finally it is worth noting that cognitive tests are usually only useful in detecting the presence of cerebral injuries when performance falls outside the specified normal range. The use of cognitive tests in hemisphericity research will, of course, involve the comparison of scores across the normal range, and there is at present little evidence to suggest that lateralised function is in fact reflected in test performance across this range. The experimental neuropsychological literature would give no support to such an assumption. In so far as it has been examined, as Dumbrower, Favero, Michael and Cooper (1981) have with the test performance of children, it has been found not to be valid. In particular the assumption that "verbal" and "nonverbal" task performance can be taken to directly index the relative functional performance of the left and right hemispheres receives no support from the literature. It is not inconceivable that simple cognitive performance measures might be devised which could serve as a measure of hemisphericity, but one has yet to be developed to which a reasonable degree of validity can be attributed.

## Externally Validated Studies

Lateral eye movements, questionnaires, and cognitive tests remain at best indirect measures of cerebral hemispheric function, and electrophysiological measures are fraught with technical difficulties. It is thus surprising that few studies of hemisphericity have sought to make an independent assessment of the validity of the measures used.

The most convincing method of validating measures of hemisphericity would probably be to show that such measures can be used to correctly identify the laterality of cerebral lesions. To date, this approach has only been used by Gordon and his co-workers, whose studies have been described in the foregoing review of the use of cognitive tests in hemisphericity research.

An alternative method that has been employed in a few studies of hemisphericity is to try to validate the hemisphericity measures against the results of visual field and dichotic listening tests. The visual field and dichotic listening techniques are, of course, themselves only indirect measures of cerebral hemispheric function, and require considerable care in the choice of procedures, but they have been quite extensively investigated. The methodological issues involved have been reviewed and discussed by Beaumont (1983b), Bryden (1982), and Young (1982).

Arndt and Berger (1978) took three "left-" and three "right-hemisphere" tests which they selected "following Bogen et al, 1972", and administered them to three occupational groups who were psychologists, lawyers or sculptors. They also employed the divided visual field technique using faces and letters as stimuli, as an independent assessment of lateral cerebral organisation. Their findings were quite clear in that there was no relationship of the asymmetry of cognitive mode, as derived from the sets of tests, or of occupational group membership, to cerebral laterality as assessed by the divided visual field technique. This result must further undermine any belief in the validity of hemisphericity as currently assessed.

Essentially similar conclusions can be reached from Gordon's (1980) finding that although his groups of dyslexic children and members of their immediate families showed a "right dominant" profile on his Cognitive Laterality Battery, neither these groups nor control groups differed in the extent of ear asymmetries in dichotic listening. Caplan and Kinsbourne (1981, 1982) did find that a verbal approach to problem solving as identified in the Word-Shape Sorting Test was associated with both reading ability and the degree of right ear advantage for identifying dichotic stop consonant-vowel syllables. Backward readers, nevertheless, did not differ from controls in asymmetry on the dichotic listening task, and this raises some doubt as to whether it is necessary to implicate differences in lateralisation in explaining these findings.

Huang (1979) reported data showing that narrow categorisers (who are superior on tasks demanding detailed or analytic processing) on Pettigrew's Category Width Scale showed a much greater degree of right ear advantage on a dichotic listening task than did broad categorisers (who are more efficient at operating a more integrated or holistic strategy). Charman (1981) reported that lecturers in arts and sciences showed very different patterns of lateralisation on a divided visual field letter recognition task, the scientists showing the usual right visual field advantage but the artists showing a left visual field advantage. Zoccolotti and Oltman (1978) found that field independent subjects tended to show a greater right visual field advantage on a letter discrimination task, and a greater left visual field advantage on a face-discrimination task.

It is surprising, in view of the importance of the findings of experiments of this kind, that they have not been more commonly performed.

## THEORETICAL BASIS OF THE CONCEPT OF HEMISPHERICITY

From our review of the empirical studies of hemisphericity, it is clear that the idea is at present inadequately grounded in fact. It is worth asking whether this is due to the poor quality of much of the work that has been done, or whether the idea of hemisphericity is itself simply unsound. There

are a number of objections to the idea of hemisphericity which can be made on theoretical grounds, which will now be discussed. Although these theoretical points are often closely interrelated, they are arranged here under three subheadings for clarity of exposition: confusions of terminology; the use of dichotomies; issues of cerebral control.

## Confusions of Terminology

There are a number of ways in which hemisphericity research has been confused by failures to define, or to agree on, the meaning of terms that have been used.

As stated in the introduction to this paper, hemisphericity refers to the idea that an individual may tend to rely on a preferred mode of cognitive processing which is linked to predominant activity on the part of either the left or the right cerebral hemisphere. This, however, leaves open a number of questions, the most important of which centre around the different possible interpretations of "preferred" and "predominant". Is it a voluntary preference, in which case the relation of a preference to another commonly used idea, that of "strategy", needs to be spelled out? Or is it involuntary? When one hemisphere predominates does the other shut down completely, or does it remain active at a somewhat reduced level? Why can't both cerebral hemispheres be active at the same time?

As might be expected, different researchers have given different explicit or implicit answers to such questions, so that conceptions of hemisphericity range from those in which the choice of cognitive mode is to some extent open to conscious choice and varies from task to task (Thompson & Bogen, 1976), to those in which one hemisphere is activated "regardless of the appropriateness of that hemisphere for task demands" (Sackeim, Packer & Gur, 1977, p. 625).

### The Use of Dichotomies

The use of dichotomies to describe the functions of the left and right cerebral hemispheres is, of course, central to hemisphericity. One of the reasons for disquiet with hemisphericity research has been that the dichotomies that have been used are not sufficiently grounded in fact. This state of affairs has largely arisen in two ways. Firstly, by investigators extrapolating too freely from the findings of split-brain studies and the small differences found under very tightly controlled conditions in normal subjects. Secondly, by the deduction of new dichotomies on the basis of their apparent association with other dichotomies already proposed. Thus, for instance, the idea that the right hemisphere is intuitive seems to have been arrived at because it looks

reasonable given that the right hemisphere has already been characterised as analogical, and this analogical characterisation was in turn arrived at because it looked reasonable given that the right hemisphere seemed to be nonverbal.

To be of lasting value, the idea of hemisphericity will have to contribute something that is not already present in the existing literature on individual differences; it must do more than simply map onto distinctions such as verbal versus nonverbal that have already been explored in some detail. This is unlikely to happen if the method of arriving at dichotomies outlined above continues to be employed.

It may in fact be the case that the idea that left- and right-hemisphere abilities can be described by any conceivable set of dichotomies will prove unworkable. Hemisphericity research is predicated on the view that suitable dichotomies can be found, because of three implicit assumptions. The first is that cerebral hemisphere differences are qualitative in nature. The second is that cerebral asymmetries reflect more general hemisphere asymmetries. The third is that these hemisphere differences exist because of fundamental incompatibilities between different psychological processes, which need to be physically separated. All of these assumptions may be questioned.

The first assumption, that cerebral hemisphere differences are principally qualitative in nature, ignores evidence indicating that several of the superiorities associated with the right cerebral hemisphere seem to be small and quantitative in nature (Gazzaniga & LeDoux, 1978; Joynt & Goldstein, 1975). This is not to deny that qualitative differences, including right hemisphere superiorities, also exist between the hemispheres.

The second assumption has been seriously criticised by LeDoux (1983). He argues that the assumption that cerebral asymmetries reflect more general hemisphere asymmetries has given rise to a number of misconceptions. His point is that the differences that have been shown to exist between the cerebral hemispheres are not global, but rather involve specific cognitive processes mediated by restricted subsets of neurons. The assumption that these relatively specific cerebral asymmetries are reflections of more general hemisphere asymmetries is unwarranted, and disregards the complexity of the asymmetries which have been found. This point can be summarised as saying that each of the cerebral hemispheres probably contains a number of qualititatively different mechanisms and that it would require considerable substantiation before any global label could be applied to the processing carried out in either.

The third assumption underlying the use of dichotomies, that cerebral hemisphere differences exist because of fundamental incompatibilites between different psychological processes, also runs into difficulties. These would include the lack of deficits observed in people whose "incompatible" processes do reside in the same hemisphere, such as some left handers (De Renzi, 1982). There are also difficulties relating to the issues of cerebral control discussed under the next subheading.

### Issues of Cerebral Control

One of the problems many people find with the idea of hemisphericity is that it seems to ignore the fact that the cerebral hemispheres work together in normal people, forming a single integrated system. In particular, it naively ascribes to the corpus callosum the status of being a nerve fibre tract that is capable of forming a co-ordinating link between incompatible processes in a way in which intrahemispheric fibre tracts are implicitly incapable. No reason has been offered as to why incompatible processes (if such exist) could not be kept separate within a single hemisphere, and we have already noted the lack of any observed deficit when this does seem to happen.

There are also serious problems in understanding how the control of mechanisms that are seen as physically separate, qualitatively different, and to some extent mutually incompatible, is achieved. If, in any sense at all, the brain contains independent processing systems that can none the less be employed for a variety of purposes (and this would apply within as well as between hemispheres), the question as to how each is allocated to a particular task becomes of central importance. Levy and Trevarthen (1976) referred to this as the problem of "metacontrol". Hemisphericity research has yet to tackle this problem in any adequate way.

## CURRENT STATUS OF HEMISPHERICITY

From the review of the empirical studies of hemisphericity presented here, it is clear that invalid tests are being used and that as a result invalid inferences have been drawn. In addition we have pointed out a number of reasons why the concept of hemisphericity is itself unsound. This might be viewed as a matter of unsatisfactory scientific endeavour, but, because of the way in which some of the research has been used, it is also of more general concern.

Gowan (1979) has discussed how procedures derived from the hemisphericity research might be used to encourage imagery, incubation and improved mental efficiency, and the general relationship between hemisphericity and superior attainment has received widespread attention (Garrett, 1976; Kane & Kane, 1979; Lee & Pulvino, 1978; Olson, 1977; Rennels, 1976). Rubenzer (1979) has similarly advocated the promotion of "right hemisphere function and problem solving". Noyce (1979) has proposed the use of certain books to generate right hemisphere stimulation and Shuman (1978) has even suggested a specific method for teaching Shakespeare's *Hamlet* "so that it aids right hemisphere development". "Ways to develop the right brain" have also been proposed by Prince (1978) and include: the use of guessing games; the use of musical backgrounds, occasionally becoming dominant over the spoken text; and prohibition of the word "no"—because "the right hemisphere has no equivalent of 'no' ". None of these ideas finds any basis in the scientific neuropsychological literature.

The point has already been made by Hardyck and Haapanen (1979) that attempts have been made to influence educational and social policy, as a result of the hemisphericity research, with the claim for a sound scientific basis which does not in fact exist. The point bears repetition. Some of the suggestions and recommendations being made are simply absurd, but others might be potentially dangerous, and should not claim the support of neuropsychology for their legitimacy.

Given the lack of foundation to the dichotomies so often used, the question arises, if the research were more rigorous, might it provide useful findings? From the neuropsychological literature concerned with human performance—divided visual field, dichotic listening, manual performance tasks and related techniques—the signs are not encouraging. We know that there are significant individual differences, as yet poorly understood, which contribute to task performance. Within individuals there is considerable, and significant, variability in performance across time and across different test procedures. Finally, there is poor correlation between different measures of cerebral laterality (Beaumont, 1982a; Berenbaum & Harshman, 1980; Colbourn, 1978; Searleman, 1980). Perhaps the most stable lateral performance measure so far devised, Geffen's Dichotic Monitoring Test (Geffen & Caudray, 1981), only achieves a reliability of about 80%. This cannot be encouraging for attempts to discover a general index, easily and quickly administered, which would characterise an individual's overall pattern of cognitive function as reflected in the balance between the cerebral hemispheres. Moreover, we have also noted reasons why the search for dichotomies that characterise left and right cerebral hemisphere functions in an overall fashion is at least unsubstantiated, and most probably wrong in principle.

On the basis of the review presented, it would seem prudent to abandon the notion of hemisphericity, at least in so far as it claims to make any reference to the lateral function of the cerebral hemispheres. Such a claim cannot be supported by current scientific studies of the cognitive functions of the cerebral hemispheres, and it is most unlikely that more thorough understanding of the relation between cognitive function and cerebral structural systems will lead to any change in this state of affairs.

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## REFERENCES

Amochaev, A., & Salamy, A. (1979) Stability of EEG laterality effects. *Psychophysiology, 16*, 242–246.

Arndt, S., & Berger, D. E. (1978) Cognitive mode and asymmetry in cerebral functioning. *Cortex, 14*, 78–86.

Beaumont, J. G. (1981) Split-brain studies and the duality of consciousness. In G. Underwood, & R. G. Stevens (Eds.), *Aspects of consciousness* (Vol. 2). London: Academic Press.

Beaumont, J. G. (Ed.) (1982a) *Divided visual field studies of cerebral organisation.* London: Academic Press.

Beaumont, J. G. (1982b) The EEG and task performance: a tutorial review. In A. W. K. Gaillard, & W. Ritter (Eds.), *Tutorials in ERP research—endogenous components.* Amsterdam: North Holland.

Beaumont, J. G. (1983a) *Introduction to neuropsychology.* Oxford: Blackwell Scientific.

Beaumont, J. G. (1983b) Methods for studying cerebral hemispheric function. In A. W. Young (Ed.), *Functions of the right cerebral hemisphere.* London: Academic Press.

Bentin, S., & Gordon, H. W. (1979) Assessment of cognitive asymmetries in brain-damaged and normal subjects: validation of a test battery. *Journal of Neurology, Neurosurgery and Psychiatry, 42,* 715–723.

Berenbaum, S., & Harshman, R. (1980) On testing group differences in cognition resulting from differences in lateral specialization: reply to Fennell et al. *Brain and Language, 11,* 209–220.

Berent, S. (1981) Lateralization of brain function. In S. B. Filskov, & T. J. Boll (Eds.), *Handbook of clinical neuropsychology.* New York: Wiley.

Berg, M. R., & Harris, L. J. (1980) The effect of experimenter location and subject anxiety on cerebral activation as measured by lateral eye movements. *Neuropsychologia, 18,* 89–93.

Bogen, J. E. (1977) Some educational implications of hemisphere specialization. In M. C. Wittrock (Ed.), *The human brain.* Englewood Cliffs, N.J.: Prentice Hall.

Bogen, J. E., DeZure, R., TenHouten, N., & Marsh, J. (1972) The other side of the brain IV: the A/P ratio. *Bulletin of the Los Angeles Neurological Societies, 37,* 49–61.

Bracken, B. A., Ledford, T. L., & McCallum, R. S. (1979) Effects of cerebral dominance on college-level achievement. *Perceptual and Motor Skills, 49,* 445–446.

Bradshaw, J. L., & Nettleton, N. C. (1981) The nature of hemispheric specialization in man. *The Behavioral and Brain Sciences, 4,* 51–91.

Bradshaw, J. L., & Nettleton, N. C. (1983) *Human cerebral asymmetry.* Englewood Cliff, N.J.: Prentice Hall.

Bruce, L. C. (1895) Notes of a case of dual brain action. *Brain, 18,* 54–65.

Bruce, E. P., Herman, J. F., & Stern, J. (1982) Lateral eye movements and the recall of spatial information in a familiar large-scale environment. *Neuropsychologia, 20,* 505–508.

Bryden, M. P. (1982) *Laterality: functional asymmetry in the intact brain.* New York: Academic Press.

Caplan, B., & Kinsbourne, M. (1981) Cerebral lateralisation, preferred cognitive mode and reading ability in normal children. *Brain and Language, 14,* 349–370.

Caplan, B., & Kinsbourne, M. (1982) Cognitive style and dichotic asymmetries of disabled children. *Cortex, 18,* 357–366.

Cashford, J. (1979) The integration of the cerebral hemispheres in poetry and mystic texts. *Gifted Child Quarterly, 23,* 56–70.

Charman, D. K. (1981) The cerebral hemispheres appear to function differently in artists and scientists. *Cortex, 17,* 453–458.

Colbourn, C. J. (1978) Can laterality be measured? *Neuropsychologia, 16,* 283–289.

Coltheart, M. (1980) Deep dyslexia: a right hemisphere hypothesis. In M. Coltheart, K. Patterson, & J. C. Marshall (Eds.) *Deep dyslexia.* London: Routledge & Kegan Paul.

Corballis, M. C. (1980) Laterality and myth. *American Psychologist, 35,* 284–295.

De Renzi, E. (1982) *Disorders of space exploration and cognition.* London: Wiley.

Dimond, S. J., & Beaumont, J. G. (Eds.) (1974) *Hemisphere function in the human brain.* London: Elek Science.

Donchin, E., Kutas, M., & McCarthy, G. (1977) Electrocortical indices of hemispheric utilization. In S. Harnad, R. W. Doty, L. Goldstein, J. Jaynes, & G. Krauthamer (Eds), *Lateralization in the nervous system.* New York: Academic Press.

Donchin, E., McCarthy, G., & Kutas, M. (1977) Electroencephalographic investigations of hemispheric specialization. In J. E. Desmedt (Ed.), *Progress in clinical neurophysiology, vol. 3, language and hemispheric specialization in man.* Basel: Karger.

Dumbrower, J., Favero, J., Michael, W. B., & Cooper, T. L. (1981) An attempt to determine the construct validity of measures hypothesized to represent an orientation to right, left or integrated hemispheric brain function for a sample of primary school children. *Educational and Psychological Measurement, 41*, 1175–1194.

Dunivin, D., & Zenhausern, R. (1981) Differential hemispheric activation and handedness and hysterical and obsessive personality styles. *Bulletin of the Psychonomic Society, 17*, 23–25.

Ehrlichman, H., & Weinberger, A. (1978) Lateral eye movements and hemispheric asymmetry: a critical review. *Psychological Bulletin, 85*, 1080–1101.

Ehrlichman, H., & Weiner, M. S. (1979) Consistency of task-related EEG assymmetries. *Psychophysiology, 16*, 247–252.

Furst, C. J. (1976) EEG alpha asymmetry and visuo-spatial performance. *Nature, 260*, 254–255.

Galin, D. (1974) Implications for psychiatry of left and right cerebral specialization. *Archives of General Psychiatry, 31*, 572–583.

Galin, D., & Ornstein, R. (1972) Lateral specialization of cognitive mode: an EEG study. *Psychophysiology, 9*, 412–418.

Galin, D., & Ornstein, R. E. (1975) Hemispheric specialization and the duality of consciousness. In H. J. Widroe (Ed.), *Human behavior and brain function*. Springfield, Ill.: C. C. Thomas.

Gallagher, R. E., & Joseph, R. (1982) Nonlinguistic knowledge, hemispheric laterality, and the conservation of inequality in nonconserving children. *Journal of General Psychology, 107*, 31–40.

Garrett, S. V. (1976) Putting our whole brain to use: a fresh look at the creative process. *Journal of Creative Behavior, 10*, 239–249.

Gazzaniga, M. S. (1983a) Right hemisphere language following brain bisection: a 20-year perspective. *American Psychologist, 38*, 525–537.

Gazzaniga, M. S. (1983b) Reply to Levy and Zaidel. *American Psychologist, 38*, 547–549.

Gazzaniga, M. S., & LeDoux, J. E. (1978) *The integrated mind*. New York: Plenum.

Geffen, G., & Caudrey, D. (1981) Reliability and validity of the dichotic monitoring test for language laterality. *Neuropsychologia, 19*, 413–423.

Gevins, A. S., Zeitlin, G. M., Doyle, J. C., Schaffer, R. E., & Callaway, E. (1979) EEG patterns during 'cognitive' tasks. II Analysis of controlled tasks. *Electroencephalography and Clinical Neurophysiology, 47*, 704–710.

Gevins, A. S., Zeitlin, G. M., Yingling, C. D., Doyle, J. C., Dedon, M. F., Schaffer, R. E., Roumasset, J. T., & Yeager, C. L. (1979) EEG patterns during 'cognitive' tasks. I Methodology and analysis of complex behaviors. *Electroencephalography and Clinical Neurophysiology, 47*, 693–703.

Golden, C. J. (1981) *Diagnosis and rehabilitation in clinical neuropsychology* (2nd edition). Springfield, Ill.: C. C. Thomas.

Gordon, H. W. (1980) Cognitive asymmetry in dyslexic families. *Neuropsychologia, 18*, 645–656.

Gordon, H., Frooman, B., & Lavie, P. (1982) Shift in hemispheric asymmetries between wakings from REM and NREM sleep. *Neuropsychologia, 20*, 99–103.

Gordon, H. W., Silverberg-Shalev, R., & Czernilas, J. (1982) Hemispheric asymmetries in fighter and helicopter pilots. *Acta Psychologica, 52*, 33–40.

Gowan, J. C. (1979) The production of creativity through right hemisphere imagery. *Journal of Creative Behavior, 13*, 39–51.

Gruzelier, J. H. (1981) Cerebral laterality and psychopathology: fact and fiction. *Psychological Medicine, 11*, 219–227.

Gur, R. C., & Reivich, M. (1980) Cognitive task-effects on hemispheric blood flow in humans: evidence for individual differences in hemispheric activation. *Brain and Language, 9*, 78–92.

Hardyck, C., & Haapanen, R. (1979) Educating both halves of the brain: educational breakthrough or neuromythology? *Journal of School Psychology, 17*, 219–230.

Hepburn, M. J. (1977) More on split-brain research and anthropology. *Current Anthropology*, *18*, 349–350.

Hirschman, E. C. (1983) Psychological sexual identity and hemispheric orientation. *Journal of General Psychology*, *108*, 153–168.

Huang, M-S. (1979) Hemispheric differentiation and category width. *Cortex*, *15*, 531–539.

Huang, M-S., & Byrne, B. (1978) Cognitive style and lateral eye-movements. *British Journal of Psychology*, *69*, 85–90.

Jaynes, J. (1976) *The origin of consciousness in the breakdown of the bicameral mind.* Boston, Mass.: Houghton Mifflin.

Joynt, R. G., & Goldstein, M. N. (1975) Minor cerebral hemisphere. In W. J. Friedlander (Ed.), *Advances in neurology*, *vol.* 7. New York: Raven Press.

Kaltsounis, B. (1979) Evidence of validity of the scale; Your Style of Learning and Thinking. *Perceptual and Motor Skills*, *48*, 177–178.

Kane, N., & Kane, M. (1979) Comparison of right and left hemisphere functions. *Gifted Child Quarterly*, *23*, 157–167.

Kaplan, C. D. (1977) More on split-brain research and anthropology. *Current Anthropology*, *18*, 346–348.

Katz, A. N. (1978) Creativity and the right cerebral hemisphere: towards a physiologically based theory of creativity. *Journal of Creative Behaviour*, *12*, 253–264.

Kinsbourne, M. (Ed.) (1978) *Asymmetrical function of the brain.* Cambridge, U.K.: Cambridge University Press.

Klein, P. S. (1980) The overlooked or misused talents of learning disabled children. *The Creative Child and Adult Quarterly*, *5*, 30–34.

Klein, R., & Armitage, R. (1979) Rhythms in human performance: $1\frac{1}{2}$ hour oscillations in cognitive style. *Science*, *204*, 1326–1328.

Konicek, R. D. (1975) Seeking synergism for man's two hemisphere brain. *Phi Delta Kappan*, *57*, 37–39.

LaTorre, R. A., Gossman, I., & Piper, W. E. (1976) Cognitive style, hemispheric specialization and tested abilities of transsexuals and nontranssexuals. *Perceptual and Motor Skills*, *43*, 719–722.

LeBoeuf, A. (1982) Lateral eye movements and personality style. *Perceptual and Motor Skills*, *54*, 970.

LeDoux, J. E. (1983) Cerebral asymmetry and the integrated function of the brain. In A. W. Young (Ed.), *Functions of the right cerebral hemisphere*. London: Academic Press.

Lee, J. L., & Pulvino, C. J. (1978) *Educating the forgotten half.* Dubuque, Iowa: Hunt Publishing Co.

LeMay, M., & Geschwind, N. (1978) Asymmetries of the human cerebral hemispheres. In A. Caramazza & E. B. Zurif (Eds.), *Language acquisition and language breakdown: Parallels and divergences*. Baltimore, Maryland: The Johns Hopkins Press.

Levinson, B. M. (1980) Comment on Martindale's "Hemispheric asymmetry and Jewish intelligence test patterns". *Journal of Consulting and Clinical Psychology*, *48*, 258–260.

Levy, J. (1983) Language, cognition, and the right hemisphere: a response to Gazzaniga. *American Psychologist*, *38*, 538–541.

Levy, J., & Trevarthen, C. (1976) Metacontrol of hemispheric function in human split-brain patients. *Journal of Experimental Psychology: Human Perception and Performance*, *2*, 299–312.

Martindale, C. (1978) Hemispheric asymmetry and Jewish intelligence test patterns. *Journal of Consulting and Clinical Psychology*, *46*, 258–260.

McCallum, R. S., & Glynn, S. M. (1979) Hemispheric specialization and creative behavior. *Journal of Creative Behavior*, *13*, 263–273.

McCandless, R. L. (1980) The bicameral mind. *Religious Education*, *75*, 436–440.

Newlin, D. B. (1981) Hemisphericity, expressivity and autonomic arousal. *Biological Psychology*, *12*, 13–23.

Noyce, R. M. (1979) Children's books for right hemisphere stimulation. *Gifted Child Quarterly*, *23*, 151–155.

O'Connor, K. P., & Shaw, J. C. (1978) Field dependence, laterality and the EEG. *Biological Psychology*, *6*, 93–109.

Oexle, J. E., & Zenhausern, R. (1981) Differential activation in good and poor readers. *International Journal of Neuroscience*, *15*, 31–36.

Olson, M. B. (1977) Right or left hemispheric information processing in gifted students. *Gifted Child Quarterly*, *21*, 116–121.

Olson, M. B. (1979) Cerebral lateralization in science. *Gifted Child Quarterly*, *23*, 142–150.

Ornstein, R. E., & Galin, D. (1976) Physiological studies of consciousness. In P. Lee, R. E. Ornstein, D. Galin, A. Deichman, & C. Tart (Eds.), *Symposium on consciousness*. New York: Viking Press.

Paredes, J. A. (1977) More on split-brain research and anthropology. *Current Anthropology*, *18*, 348–349.

Paredes, J. A., & Hepburn, M. J. (1976) The split-brain and the culture-and-cognition paradox. *Current Anthropology*, *17*, 121–127.

Prince, G. (1978) Putting the other half of the brain to work. *Training*, *15*, 57–61.

Ray, W. J., Georgiou, S., & Ravizza, R. (1979) Spatial abilities, sex differences, and lateral eye movements. *Developmental Psychology*, *15*, 455–457.

Rekdal, C. K. (1979) Hemispheric lateralization, cerebral dominance, conjugate saccadic behavior, and their use in identifying the creatively gifted. *Gifted Child Quarterly*, *23*, 101–108.

Rennels, M. R. (1976) Cerebral symmetry: an urgent concern for education. *Phi Delta Kappan*, *57*, 471–472.

Reynolds, C. R., & Torrance, E. P. (1978) Perceived changes in styles of learning and thinking (hemisphericity) through direct and indirect training. *Journal of Creative Behavior*, *12*, 247–252.

Richardson, A. (1978) Initial eye movement responses. *Bulletin of the British Psychological Society*, *31*, 187.

Rossi, E. (1977) The cerebral hemispheres in analytic psychology. *Journal of Analytic Psychology*, *22*, 32–51.

Rubenzer, R. (1979) The role of the right hemisphere in learning and creativity implications for enhancing problem solving ability. *Gifted Child Quarterly*, *23*, 78–100.

Rugg, M. D. (1982) Electrophysiological studies. In J. G. Beaumont (Ed.), *Divided visual field studies of cerebral organisation*. London: Academic Press.

Sackeim, H. A., Packer, I. K., & Gur, R. C. (1977) Hemisphericity, cognitive set and susceptibility to subliminal perceptions. *Journal of Abnormal Psychology*, *86*, 624–630.

Samples, R. (1975) Educating for both sides of the human mind. *Science Teacher*, 42, 21–23.

Sandel, A., & Alcorn, J. D. (1980) Individual hemisphericity and maladaptive behaviors. *Journal of Abnormal Psychology*, *89*, 514–517.

Säring, W., & Von Cramon, D. (1980) Is there an interaction between cognitive activity and lateral eye movements? *Neuropsychologia*, *18*, 591–596.

Searleman, A. (1980) Subject variables and cerebral organization for language. *Cortex*, *16*, 239–254.

Shevrin, H., Smokler, I., & Kooi, K. A. (1980) An empirical link between lateral eye movements and lateralized evoked-response brain potentials. *Biological Psychology*, *15*, 691–697.

Shuman, R. B. (1978) Inquiry and discovery as teaching strategies in English. *Illinois Schools Journal*, *58*, 18–27.

Sidtis, J. J., Volpe, B. T., Wilson, D. H., Rayport, M., & Gazzaniga, M. S. (1981) Variability in right hemisphere language function after callosal section: evidence for a continuum of generative capacity. *Journal of Neuroscience*, *1*, 323–331.

Smokler, I. H., & Shevrin, H. (1979) Cerebral lateralization and personality style. *Archives of General Psychiatry*, *36*, 949–954.

Springer, S. P., & Deutsch, G. (1981) *Left brain, right brain.* San Francisco: Freeman.

Takeda, M., & Yoshimura, H. (1979) Lateral eye movement while eyes are closed. *Perceptual and Motor Skills, 48,* 1227–1231.

TenHouten, W. D. (1976) More on split-brain research, culture, and cognition. *Current Anthropology, 17,* 503–506.

TenHouten, W. D. (1977) More on split-brain research and anthropology. *Current Anthropology, 18,* 344–346.

TenHouten, W. D., Thompson, A. L., & Walter, D. O. (1976) Discriminating social groups by performance on two lateralized tests. *Bulletin of the Los Angeles Neurological Societies, 41,* 99–108.

Thompson, A. L., & Bogen, J. E. (1976) More on the question of cultural hemisphericity. *Bulletin of the Los Angeles Neurological Societies, 41,* 93–98.

Torrance, E. P. (1982) Hemisphericity and creative functioning. *Journal of Research and Development in Education, 15,* 29–37.

Torrance, E. P., & Mourad, S. (1978) Some creativity and style of learning and thinking correlates of Guglielmino's Self-Directed Learning Readiness Scale. *Psychological Reports, 43,* 1167–1171.

Torrance, E. P., & Mourad, S. (1979) Role of hemisphericity in performance on selected measures of creativity. *Gifted Child Quarterly, 23,* 44–55.

Torrance, E. P., & Reynolds, C. (1980) *Norms-Technical Manual for Your Style of Learning and Thinking.* Athens, Georgia: Department of Educational Psychology, University of Georgia.

Torrance, E. P., Reynolds, C. R., Riegel, T., & Ball, O. (1977) Your Style of Learning and Thinking, Forms A and B: preliminary norms, abbreviated technical notes, scoring keys and selected references. *Gifted Child Quarterly, 21,* 563–573.

Tucker, G. H., & Suib, M. R. (1978) Conjugate lateral eye movement (CLEM) direction and its relationship to performance on verbal and visuospatial tasks. *Neuropsychologia, 16,* 251–254.

West, S. A. (1975) Creativity, altered states of consciousness, and artificial intelligence. *Journal of Altered States of Consciousness, 2,* 219–230.

Wheatley, G. H. (1977) The right hemisphere's role in problem solving. *Arithmetic Teacher, 25,* 36–39.

Wheatley, G. H., Mitchel, R., Frankland, R. L., & Craft, R. (1978) Hemispheric specialization and cognitive development: implications for mathematics in education. *Journal for Research in Mathematics Education, 9,* 20–31.

Whitaker, H. A., & Ojemann, G. A. (1977) Lateralization of higher cortical functions: a critique. *Annals of the New York Academy of Sciences, 299,* 459–473.

Wiet, S. G. (1981) Some quantitative hemispheric EEG measures reflecting the affective profile of students differing in university academic success. *Biological Psychology, 12,* 25–42.

Wiet, S. G., & Goldstein, L. (1981) Successful and unsuccessful university students: quantitative hemispheric EEG differences. *Biological Psychology, 8,* 273–284.

Young, A. W. (1982) Methodological and theoretical bases of visual hemifield studies. In J. G. Beaumont (Ed.), *Divided visual field studies of cerebral organisation.* London: Academic Press.

Zaidel, E. (1983) A response to Gazzaniga: language in the right hemisphere, convergent perspectives. *American Psychologist, 38,* 542–546.

Zangwill, O. L. (1976) Thought and the brain. *British Journal of Psychology, 67,* 301–314.

Zenhausern, R. (1978) Imagery, cerebral dominance and style of thinking: a unified field model. *Bulletin of the Psychonomic Society, 12,* 381–384.

Zenhausern, R., & Gebhardt, M. (1979) Hemispheric dominance in recall and recognition. *Bulletin of the Psychonomic Society, 14,* 71–73.

Zenhausern, R., & Nickel, L. (1979) Hemispheric dominance and maze learning. *Bulletin of the Psychonomic Society, 14,* 435–436.

Zoccolotti, P., & Oltman, J. (1978) Field dependence and lateralization of verbal and configurational processing. *Cortex*, *14*, 155–168.

Zook, J. A., & Dwyer, J. H. (1976) Cultural differences in hemisphericity: a critique. *Bulletin of the Los Angeles Neurological Societies*, *41*, 87–90.

## REFERENCE NOTES

1. Dawson, S. L., Tucker, D. M., & Swenson, R. A. (1981) *Lateralized cognitive style and self-description*. Unpublished manuscript. University of North Dakota.