

HEMISPHERIC ASYMMETRY: VARIANCE IN DIFFERENT CONDITIONS
AND PERSONALITY TYPES

by

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ABSTRACT

A new dichotic listening (DL) technique, based on a psychophysical threshold procedure, which provides ordinal scale measurement of lateral asymmetry, was used to investigate variation in the size of ear advantage for verbal vs manual response modes across three categories of stimuli: abstract words, concrete words, and emotional words. The procedure, which measures discrimination ability in decibels as the interaural intensity difference (IID) required for a specific accuracy, demonstrated that mode of response and stimulus type play significant confounding roles in the determination of ear asymmetry on a semantic classification task. A multivariate repeated measures analysis of variance (MANOVA) of the data of 60 right handed male subjects between the ages of 18 and 30 years revealed a significant main effect for order of target presentation and a significant main effect for stimulus category. Mode of response produced no significant main effect. However, a significant mode of response by stimulus category interaction confirmed the hypothesis that these two factors contribute confounding effects in the measure of ear asymmetry. For manual responders, abstract words elicited a significantly greater right ear advantage (REA) than did concrete words, which in turn differed significantly from emotional words, which

elicited a non-significant left ear advantage (LEA). Verbal responders showed no comparable significant difference in the size of the REA among the stimulus categories. An additional hypothesis that low extraversion scores as measured on the Eysenck Personality Scale would correlate positively with REA scores failed to be confirmed. The implications of stimulus type and response mode confounds are discussed in terms of a hemispheric priming theory. Methodological recommendations for clinical applications and future investigations with the DL paradigm are provided. The author also discusses limitations related to investigations of the relation between hemispheric asymmetry measures and personality indices of individual cognitive style.

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DEDICATION

This thesis is gratefully dedicated to my parents, Pauline
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GENERAL INTRODUCTION

"Nine times out of ten, in the arts as in life, there is actually no truth to be discovered; there is only error to be exposed." (Mencken, 1922, p. 93).

Statement of the Problem

There has been a longstanding controversy with respect to functional asymmetry for language within the normal human brain and a variety of populations and methods have yielded disparate results (Berent, 1981; Bogen, 1979; Effron, Bogen, and Yund, 1977; Damasio, 1979; Hecaen and Albert, 1978; Levy, Nebes, and Sperry, 1971; Lezak, 1983; Sparks and Geschwind, 1968; Walsh, 1978).

The contradictory findings are difficult to explain, but may be accounted for in part by methodological difficulties involving:

(1) variability in task requirements, (2) confounding due to differences in stimulus type and construction, (3) inappropriate or lack of statistical analyses, and (4) lack of uniformity in subject characteristics; for example, when patient samples are investigated, there is little confirmation of the type and extent of brain damage (Molfese, Molfese, and Parsons, 1983). Additional complications arise when findings derived from studies

involving brain damaged populations are generalized to those without neurological damage (Beaumont, 1983; Bryden, 1982; Crockett, Clark, and Klonoff, 1981; Searleman, 1983). As well, a preponderance of studies that presume a priori speech in the left hemisphere and visuospatial functions in the right hemisphere has resulted in relatively few well controlled investigations of right-hemisphere speech capabilities (Beaumont, 1983).

On a more conceptual level, many reports reflect the lack of a clearly stated operational definition of the mechanism underlying the model of hemispheric asymmetry being investigated. This complicates the process of testing the adequacy of the methodology for the proposed model (Graves and Morley, 1986). Controversies gravitating around functional asymmetry may be clarified as much by a review and critique of the theories believed to underlie functional asymmetry as by a clarification of the limitations inherent in each method purported to test a specific theory. This investigation aims toward such goals.

Some investigators account for functional hemispheric asymmetries on the basis of underlying structural anatomical differences between the two hemispheres (e.g., Geschwind and Levitsky, 1968; LeMay and Geschwind, 1978; Wada, 1976; Wada, Clarke, and Hamm, 1975; Witelson, and Pallie, 1973). This position may be said to reflect the continued influence of "localizationist" theory (e.g., Wernicke, 1908) in

contemporary neuropsychological theories.

Other investigators maintain that because functional asymmetry is operationally defined in terms of observable differences in behavior, relying solely on structural anatomical and/or physiological differences between the hemispheres may provide an inadequate explanation of functional differences (Beaumont, 1983; Bryden, 1982; Corballis, 1983; LeDoux, 1983; Luria, 1966). This approach considers functional asymmetries to reflect the dynamics of spreading neural excitation from one cortical area to adjacent areas. This position may be argued to reflect the influence of hierarchical models of brain organization such as had been advanced by John Hughlings Jackson (Rosner, 1974).

As an alternative to either of these models, Bryden (1982) has suggested that there may be different optimal levels of activation for the two hemispheres and that by manipulating the conditions under which each hemisphere may function most efficiently, it may be possible to observe hemispheric asymmetries. This position suggests that functional hemispheric asymmetries may not necessarily be fixed, but rather, may be relatively flexible. If this were the case, it is conceivable that under appropriate experimental conditions, such flexibility might be systematically observed. In the face of such evidence, traditional theories would need certain revisions to account

for such findings. Flexibility in hemispheric asymmetry for language might then be better understood in terms of the cognitive processes that underlie the functional differences rather than in strict localizationist terms. Such findings would also raise the possibility that there may exist multiple sources capable of eliciting lateral asymmetry for speech in everyday behavior. The brain's flexibility might also allow similar behavioral responses to different environmental contexts, and/or different behavioral responses to apparently similar environmental contexts. Individual experience may also be capable of producing differential patterns of lateral asymmetry for speech.

In a more general context, Bever (1983) has suggested that physiological, experiential, and cognitive factors may contribute to lateral asymmetries. With regard to hemispheric asymmetry for speech, a similarly "open ended" approach may also prove useful in clarifying some of the current controversies generated by discrepant experimental findings. Using such reasoning, some investigators have suggested that right-hemisphere linguistic capabilities may be demonstrated to be a function of the ability to process concrete language in imageable terms (Day, 1977; Hines, 1976; Paivio, 1971) or as a function of its superior efficiency at mediating emotions (Moscovitch, 1973, 1976, 1983). However, few studies have presented an independently motivated theory of cognitive behavior to test against their model of

functional asymmetry (Bever, 1983). In fact, most studies of hemispheric asymmetry for speech have been fraught with methodological problems that have severely limited the inferential process.

The development of methods for the investigation of hemispheric asymmetries has a long history. With continued technological advancements, these methods have been progressively refined. The discussion which follows reviews the pattern of this progress and briefly outlines some of the more common investigative techniques currently applied in lateralization research. Methodological weaknesses inherent in each method shall be highlighted as potential sources of confound in the determination of lateralized linguistic functions in normal individuals.

Finally, a cognitive model of speech processing will be advanced on the basis of the data derived from an experiment designed to evaluate the relative influence of various factors that are known to contribute to hemispheric asymmetries for speech.

Historical Background

Since the first reports (Broca, 1861; 1865; Dax, 1836) that for the majority of right-handed individuals, the left cerebral hemisphere dominates the mediation of speech production, numerous replications of this phenomenon have established its validity (Levy, 1974; Penfield and Roberts, 1959; Pratt and Warrington, 1972; Wada and Rasmussen, 1960;

Zangwill, 1960). In fact, most investigators currently regard the left hemisphere as dominant for speech perception as well as speech production (Beaumont, 1983; Bryden, 1982; Hecaen and Albert, 1978; Kimura, 1967; Springer and Deutsch, 1981; Searleman, 1977, 1983; Treisman, 1969; Walsh, 1978). However, although many of the early investigators agreed that the left hemisphere is predominantly responsible for the production of language, they also believed that the right hemisphere plays a significant role in the perception of language (Searleman, 1977). Jackson (1864), maintained that if expressive faculties could be demonstrated to be localized in the left hemisphere, it was equally plausible that linguistic perceptual processes could be localized in the right hemisphere. Jackson (1876) and Gowers (1887) also held that the right hemisphere was capable of producing speech such as automatic phrases and expletives. As well, Broca (1865) had advocated that both hemispheres are capable of understanding speech.

In light of these early insights, it is surprising that so many investigators would later adopt a categorical view of functional hemispheric asymmetry, and describe the left hemisphere as verbal-analytic or concerned with sequential processing, and the right hemisphere as visuo-spatial or concerned with holistic processing (see Bryden, 1982 for a thoughtful discussion). The most evident characteristic of such simplistic views of brain organization would appear to

be that they distract one's attention from issues such as bi-hemispheric or trans-callosal information processing models of brain organization. The fact that so many investigators have relatively ignored numerous reports of evidence suggesting right-hemisphere linguistic capabilities may partly account for the persistent view that the left hemisphere alone is responsible for linguistic processing (Beaumont, 1983). The following review will attempt to demonstrate for the reader that with regard to linguistic processing, the right hemisphere may be silent, but this need not suggest that it is inactive.

Historically, the greatest proportion of information regarding right-hemisphere language functions has come from clinical investigations. The contemporary period of behavioral neurology and neuropsychology, as an emerging independent discipline, began with the application of modern experimental procedures and systematic investigations of numerous cases of traumatic lesions during the Second World War (Beaumont, 1983). It is understandable that lesion studies should have played such a significant role in early investigations. Obvious ethical considerations preclude the direct exploration of a normal healthy brain. Thus, the principal source of knowledge regarding the relative involvement of the two cerebral hemispheres in relation to speech has been from observations of patients with traumatic brain lesions (Berent, 1981; Kimura, 1973). Such

investigations have provided valuable data. They have also offered the disadvantage that inferences regarding hemispheric asymmetries in normal brains have been based mainly on patients whose brain damage may have compromised not only the integrity of specific functional systems within the cerebrum, but also their interaction (Kimura, 1973). Therefore, the extent to which inferences regarding hemispheric asymmetries derived from such sources are generalizable to normal healthy brains is an important issue (Berent, 1981). As mentioned above, this problem is often compounded by poor sampling procedures and the aggregation of various lesion groups under the generic rubric "brain damaged" (see Bornstein & Matarazzo, 1982, for a thoughtful review). As well, many inappropriate inferences may be accounted for by a lack of consideration for such factors as age of traumatic or insidious onset, and the functional effects of systemic and metabolic compensatory reactions to various types of brain injury (Spreeen, Tupper, Risser, Tuokko, & Edgel, 1984). With these caveats in mind, a brief review of the methods used for studying cerebral hemispheric asymmetry follows.

Investigative Methods

Three principle methods have governed the investigation of the relative specialization of the cerebral hemispheres: (1) clinical studies; (2) invasive and non-invasive direct observation techniques, and (3) non-invasive indirect

observation techniques. Prior to 1960, almost all the data on hemispheric asymmetry of function were derived from clinical studies involving patients with localised cortical lesions, patients undergoing commissurotomy, and hemidecorticate patients (Beaumont, 1983). With the advent of computer technologies, important advancements in electrophysiologic, radiologic, and nuclear science medicine, which had begun to emerge in the second half of this century, were accelerated and refined. Such developments have facilitated direct observations of cerebral activity in both patients and normal subjects. The direct observation methods that are more commonly used in hemispheric asymmetry studies include: (1) electroencephalogram (EEG); (2) auditory evoked responses (AER); (3) regional cerebral blood flow (rCBF), and (4) positron emission tomography (PET). More recent indirect methods, commonly used in research paradigms involving observations of performance in normal subjects, are based on lateralised stimulus presentation and include: (1) tactile presentation; (2) divided visual field, and (3) dichotic listening (Bryden, 1982; Corballis; 1983).

CLINICAL METHODS

Structural Anatomical Studies

The notion that cerebral asymmetries may be related to different functions has a long history (Broca, 1865; Cunningham, 1892; Dax, 1836; Wernicke, 1908; Wigan, 1844).

Recent reports of anatomical differences between the two cerebral hemispheres (e.g., Geschwind and Levitsky, 1968; LeMay and Geschwind, 1978; Wada, 1976; Wada et al., 1975; Witelson, and Pallie, 1973) have led to a resurgence of interest in the relative importance of structural differences in relation to functional asymmetries in behavior.

Galaburda, LeMay, Kemper, and Geschwind (1978) have reported data based on carotid angiography showing a relationship between handedness and structural asymmetries. They found it more common for the brains of right-handers than those of left-handers to show a Sylvian Fissure that is longer and more horizontally oriented on the left, and a right Sylvian fissure that is angled more sharply upward. Similarly, LeMay (1977) has reported that when viewed from the top, most brains demonstrate a counterclockwise torque; the frontal lobe is wider and protrudes further forward on the right, whereas the occipital lobe is wider and protrudes further to the rear on the left. Computerized axial tomography (CT) scans have shown that this asymmetry is more common among right-handers than among left-handers (Corballis, 1983). A similar pattern of asymmetry has been observed for the structure of the occipital horns of the lateral ventricle (McRae, Branch, and Milner, 1968). For the majority of right-handers, the horn on the left is longer, whereas for left-handers, the two sides are equivalent. A number of studies have also found evidence that the left

temporal planum tends to be larger in both sexes (Geschwind and Levitsky, 1968), and that males have greater temporal asymmetries than females (Wada et al., 1975). Because the left temporal planum is one of the language-mediating regions overlapping Wernicke's area, a number of investigators have deemed it reasonable to suppose that this anatomical asymmetry bears an important relationship to left-hemisphere specialization for language (Corballis, 1983; LeMay and Geschwind, 1978). However, this evidence is suggestive at best, and there is as yet no direct evidence to demonstrate that a relationship between this anatomical asymmetry and functional asymmetry for language exists (Bryden, 1982; Corballis, 1983). Furthermore, sample sizes tend to be small and variability so great in these investigations that statistical differences are generally insignificant (Bryden, 1982). As well, the distribution of structural asymmetries reported is not always as extreme as is usually given for speech lateralization. Geschwind and Levitsky (1968) found the left temporal planum was larger in only 65% of cases, the right temporal planum was larger in 24% of cases, with no difference in 11% of cases. Wada (1976) has reported that in 100 adult brains, the left temporal planum was larger in 82 cases, the right in 10 cases, with no difference in 8 cases.

The core problem with models based on structural anatomical studies is that by definition, the procedure is post-mortem and provides no assurance that the patterns of

cerebral asymmetry observed relate in any consistent fashion to meaningful behavior (Bryden, 1982). A considerably more popular method for inferring cerebral asymmetry for language has been the observation of handedness.

Handedness Studies

The importance of handedness in relation to functional cerebral asymmetry for speech also has a long history (Broca, 1861, 1865; Dax, 1836; Porac and Coren, 1981). Numerous investigations have continued to emphasize the relevance of handedness as a possible determinant of hemispheric "dominance" for speech (Beaumont, 1974; Dimond, 1972; Geschwind and Galaburda, 1985; Wada and Rasmussen, 1960). This inference has largely been based on the observation that unilateral (left-hemisphere) brain lesions in right-handers result in aphasia in approximately 90%-99% of cases (Levy, 1974; Penfield and Roberts, 1959; Pratt and Warrington, 1972; Wada and Rasmussen, 1960; Zangwill, 1960). Similar methods have produced estimates that 50%-70% of left-handers also have linguistic functions mediated primarily by the left-hemisphere (Hecaen and Sauguet, 1971; Piercy, 1964; Roberts, 1969; Wada and Rasmussen, 1960; Warrington and Pratt, 1973; Zangwill, 1967). These findings imply that for most individuals, the left-hemisphere mediates linguistic functions. However, a number of investigators have suggested that in left-handers speech may be less extensively lateralized than in right-handers (Beaumont, 1974; Bryden,

1965, 1982; Kimura, 1967). A number of researchers have reported that a lesion in either hemisphere is more likely to produce at least a transient aphasia in left-handers than in right-handers (Gloning, Gloning, Haub, and Quatember, 1969; Gloning, and Quatember, 1966; Hecaen and Piercy, 1956; Humphrey and Zangwill, 1952a, 1952b). This evidence may be seen as an indication that in left-handers, speech may be bilaterally represented. As well, many investigators have reported that more left-handers typically recover more linguistic functions, and generally do so more rapidly than do right-handers (Botez, and Crighel, 1971; Goodglass, and Quadfasel, 1954; Luria, 1970; Zangwill, 1960; 1964). This may be additional evidence that left-handers have bilateral speech representation.

Despite a considerable number of studies, the exact relationship between handedness and language lateralization remains unclear (Searleman, 1977). This difficulty is apparently due to the fact that handedness has proven to be a difficult attribute to measure in a standardized manner and there exist a number of different methods for its assessment, with self-report questionnaires providing the most commonly used, but not necessarily the most valid index (Annett, 1972; Beaumont, 1974; Coren, and Porac, 1978; Oldfield, 1971; Porac, and Coren, 1981; Searleman, 1977). There also seems to be some confusion of terms; some authors speak of cerebral dominance and assume that measures of handedness, footedness,

and eye dominance all are indices of the same underlying asymmetry. Yet, these measures never correlate perfectly. Furthermore, as an attribute, handedness is best characterized as varying along a continuum that varies from one individual to the next. However most investigators have considered it as a dichotomous variable (Annett, 1970; Benton, 1965; Porac and Coren, 1981; Shankweiler and Studdert-Kennedy, 1975; Zangwill, 1960). This has led to some difficulties in the determination of the relative relationship between handedness and hemispheric asymmetry for speech. The issue has been a long-standing one.

Lesion Studies

Lesion studies have been contributing valuable information to functional hemispheric asymmetries since Broca's (1861; 1865) initial reports. They are not, however, without pitfalls. The rationale underlying such studies is that localised lesions in specific regions of the cortex (established by physical investigation) tend to produce observable behavioral deficits. Repeated observations of patients allow the examiner to correlate the site of a lesion with the observed behavioral deficit, and to infer the function served by the damaged cortical area.

Such studies are perforce ex-post-facto and correlational in nature. The implication is that no causal relationship may be inferred; for example, it would be erroneous to infer that a patient's linguistic functions are

localized in the left hemisphere merely on the basis of the observation that a lesion in the left hemisphere is followed by an aphasia; the alternative explanation that the patient's lesion impaired his expressive mechanisms, but that his perceptual speech system was intact would be equally plausible.

In practical settings, a more basic problem with this method is that it cannot control for the relative contribution of inhibitory and facilitatory effects which might follow from cortical damage (Beaumont, 1983; Spreen et al., 1984). Such methods lack not only validity in physiological terms, but suffer also from poor validity in cognitive terms (Weiskrantz, 1968; 1973). As well, the design of such research studies is complicated by difficulties in matching left-hemisphere and right-hemisphere lesions of comparable size and location so that patients may be compared on two matched tasks to demonstrate double dissociation of function (Weiskrantz, 1968).

A final difficulty arises with regard to lack of specificity in demarcating cortical areas with functional losses (Bogen and Bogen, 1976; Ojemann and Whitaker, 1978). Because of these methodological difficulties, many lesion studies clearly do not provide a sufficiently adequate basis from which to generalize hemispheric asymmetries to normal populations. In the light of such difficulties it is difficult to accept without reservation, early reports (e.g.,

Andersen, 1951; Critchley, 1962; Eisenson, 1962) of right-hemisphere lesions giving rise to subtle linguistic deficits.

A more precise study of the linguistic deficits of right-hemisphere brain damaged patients was conducted by Lesser (1974) who used syntactic, semantic, and phonological tests. Fifteen left-hemisphere damaged patients were compared to 15 right-hemisphere damaged patients and 15 non-brain damaged controls. Nine patients with bilateral frontal leucotomies were also included in the series. The syntax task had 80 items illustrating pictures of two spoken sentences which differed in only one respect (word order, preposition, tense, plurality, etc.). The subject had to point to the item which corresponded to the sentence spoken by the examiner (e.g., "He walks" or "They walk"). The semantic task tested word association ability. Thirty stimulus words were illustrated, together with three words most frequently associated with it (e.g., pencil, paper, pen, write). The subject's task was to point to the picture named by the examiner. The phonological test had 20 target words paired with 3 distractor words, which were most commonly mistaken for the target when spoken against white noise (e.g., porch, torch, scorch, court). The subject was required to point to the picture which corresponded to the target word named by the examiner.

Lesser's results indicated that the right-hemisphere damaged patients were not impaired in their use of syntax or phonological discrimination, but were markedly impaired in their ability to make semantic decisions. Since both the phonological and semantic decision tasks utilized a format of picture verification, with four pictures placed in a square on each card, and the subjects performed appropriately on the phonological task, Lesser (1974) argued that the semantic deficit was not due to unilateral neglect or the placement of stimuli. She speculated that right-hemisphere damage interfered with the understanding of single words, but did not interfere with syntactic interpretation, implying that these functions were mediated by the left hemisphere.

In another semantically based task (a false recognition paradigm using both visual and verbal auditory modalities), Rausch (1981) demonstrated that patients with left temporal lobectomies made significantly more false recognition errors than other patients on semantically or acoustically related words during both auditory and visual testing. Patients with right temporal lobectomies did not differ from normal controls on the auditory task, but made significantly fewer false recognition errors than controls on the visual task. Rausch (1981) suggested that this dissociation between auditory and visual modalities reflects a breakdown in the encoding of the visual attributes of the verbal material, and

that the right hemisphere may play a greater role than the left in the analysis of visual features of verbal material.

Data presented by Jones-Gotman and Milner (1978) appear to support Rausch's (1981) hypothesis. On a paired associates learning task using concrete (high imagery), high frequency words, patients with right temporal lobectomies performed poorly. On a task using abstract (low imagery) words, they performed as well as normal controls. In contrast to the normal controls, the right temporal lobectomy patients could not use visual imagery mnemonic devices to aid their recall of high imagery words. Thus, their deficit appeared to be one of image-mediated verbal learning (Millar and Whitaker, 1983).

More recently, in a series of well controlled studies, Gainotti, Caltagirone, and Miceli (1979), and Gainotti, Caltagirone, Micelli, and Masullo (1981), consistently found that right-hemisphere lesions produced a selective disorder at the level of semantic language on two multiple choice tasks of semantic-lexical discrimination. The stimuli were presented with instructions to match a stimulus word with the the picture item to which it corresponded. Fifty patients were tested; 36 had right-hemisphere cerebrovascular accidents and 14 had right-hemisphere tumor. The results indicated that the patients were significantly worse than normal controls on the multiple choice semantic discrimination task, but did not differ significantly from

normals on the phoneme discrimination task. The authors interpreted their findings as supportive of the assumption that lexical representation of language is relatively autonomous from the phonological and syntactic structures, and that the neural mechanisms underlying lexical-semantics, phonology, and syntax may be partly independent. They concluded that the right hemisphere probably contributes to normal linguistic (i.e., semantic) processing, especially in the comprehension of spoken words.

Commissurotomy Studies

Commissurotomy, or "split-brain" patients, typically undergo an operation in which the forebrain commissures are sectioned for the relief of intractable epilepsy of long standing duration, the spreading of which may no longer be controlled pharmacologically with anticonvulsants (Gazzaniga, 1970; Gazzaniga and LeDoux, 1978; Dimond, 1972; Searleman, 1977; Zaidel, 1978). The operation calls for the sectioning of the corpus callosum, sometimes together with the anterior commissure (Gazzaniga, 1970). The result is that cortico-cortical communication between the left and right hemispheres is severed (Gazzaniga, 1970; Dimond, 1972). Functional differences between the hemispheres may be investigated in relative isolation when stimuli are presented to sensory channels arriving at a single hemisphere (Gazzaniga, 1970; Searleman, 1977; Trevarthen, 1975; Zaidel, 1978).

Investigations with commissurotomed patients have consistently shown that the right hemisphere's ability to comprehend language far outstrips its ability to produce it in either the oral or the written modality (Gazzaniga, 1970; Gazzaniga and Sperry, 1967; Nebes, and Sperry, 1971; Sperry and Gazzaniga, 1967; Zaidel, 1976, 1977, 1978). Such investigations have demonstrated that the right hemisphere performs poorly on tasks of phonemic analysis (Springer and Gazzaniga, 1975; Zaidel, 1974, 1978), has limited syntactic ability (Gazzaniga, 1970; Zaidel, 1978), and can comprehend the meaning of single words (Zaidel, 1976, 1978). Evidence indicates that the right hemisphere can mediate visually presented noun-words more efficiently than verbs (Gazzaniga, Bogen, and Sperry, 1967), but can apparently mediate the comprehension of verbs as well as nouns when they are presented orally (Zaidel, 1981).

Generally, commissurotomy studies have shown that the representation of language is lateralized toward the left hemisphere and that this pattern of functional asymmetry is considerably more pronounced with respect to speech production than it is with respect to comprehension. The right hemisphere, although apparently mute, appears able of comprehending language at a level that differs only quantitatively from the level achieved by the left hemisphere. However, it would seem more proficient in the

processing of spoken than of written language (Corballis, 1983).

Although studies involving commissurotomy patients have contributed substantially to the popularization of laterality issues, they have done so in the absence of a healthy skepticism (Millar and Whitaker, 1983). Data derived from split-brain patient studies should be interpreted cautiously (Beaumont, 1983; Whitaker and Ojemann, 1977; Millar and Whitaker, 1983). On methodological grounds, there are a number of important issues that such investigations must face.

Firstly, the sample sizes in split-brain studies are small and actually constitute a series of case histories that lack experimental control and statistical validation (Beaumont, 1983; Millar and Whitaker, 1983). In fact, the majority of the data in the literature were essentially derived from seven patients, with considerable variation in performance and neurological status, as well as, degree of extracallosal pathology, which may have contributed to the observed deficits (Beaumont, 1983; Whitaker and Ojemann, 1977). Thus, in the context of neuropsychological research, reports of right-hemisphere speech capabilities in split-brain patients must take into account the history and locus of extracallosal brain damage. In light of the probability that long-standing lesions prior to surgery may be associated with some reorganization of functions in these

patients, and that the surgery itself may have compromised the intact hemisphere, it is reasonable to assume that the non-brain-damaged hemisphere of the split-brain patients probably cannot be compared directly to functions of the same hemisphere in a normal subject (Millar and Whitaker, 1983). Data interpretation should proceed cautiously.

A second difficulty is that split-brain patients have been observed to develop complex strategies allowing subtle bi-hemispheric cueing in experimental paradigms designed to test lateralized hemispheric functions (Gazzaniga, 1970; Gazzaniga and Hillyard, 1971). Therefore, in view of the abnormal neurological status of the commissurotomy patients and potentially inadequate experimental controls for ingenious cross-cueing strategies generated by these patients, problems of interpretation arise, and limit the extent to which findings of right-hemisphere speech may be generalized to normal subjects.

Finally, the role of subcortical structures in the processing of speech and language may play an additional confounding role in such studies (Searleman, 1977). There is growing evidence to suggest that the thalamus, particularly the pulvinar nucleus of the thalamus, may be involved in linguistic processing (Brown, 1975; Ojemann, 1975; Penfield and Roberts, 1959; Riklan and Cooper, 1975). However, since the specific role of subcortical structures is as yet poorly understood with regard to speech processing, the parsing of

the relative contributions of cortical and subcortical structures, cerebral reorganization, and cross-cueing strategies present tremendous obstacles to our understanding of hemispheric asymmetries in split-brain patients.

Hemidecortication Studies

The surgical procedure of hemidecortication consists of the excision of one cortical hemisphere as a radical intervention for the treatment of incurable and otherwise fatal tumors, or to alleviate the disabling effects of infantile hemiplegia and epilepsy (Searleman, 1977). The misnomer "hemispherectomy" is often used to describe this procedure, but in reality, parts of the basal ganglia and the thalamus are left intact (Dimond, 1972; Searleman, 1977). Usually, only the frontal, temporal, parietal, and occipital lobes are excised (Dimond, 1972).

Interpretations of normal hemispheric asymmetries based on the performance of hemidecorticate patients present even greater difficulties than those based on commissurotomy patients (Beaumont, 1983; Corballis and Morgan, 1978; Kinsbourne and Smith, 1974). The effects of hemidecortication on linguistic functions may show considerable variability depending on the age of onset, and whether the pathology is of an insidious or acute nature (Searleman, 1977).

Selnes (1974) has cautioned that interpretations of adult hemidecorticate reports should be guarded by issues

such as: (1) possible effects of surgical trauma on right-hemisphere linguistic ability, (2) the degree to which language is lateralized post-operatively in the patients, and (3) the degree to which post-operative right-hemisphere language may be due to residual skills from earlier developmental stages.

Left or right hemispherectomy for infantile hemiplegia, if performed during the first few years of life, usually results in the normal acquisition of language in almost all instances (Zangwill, 1960, 1964). Phonological and semantic systems reportedly transfer well with no discernable differences (Dennis and Whitaker, 1977; Kohn, 1980). This operation is rarely performed in adults with a proliferating tumor (Beaumont, 1983). In such instances, the patient generally has either a severe permanent post-operative aphasia with gross impairment of language functions if the left hemisphere is excised, or impaired visuospatial abilities with intact linguistic functions if the right hemisphere is excised (Bruell and Albee, 1962; Searleman, 1977). Although adult left hemidecorticate patients tend to have dramatic post-operative impairments in language production and propositional speech, they are often reported to show considerable verbal comprehension ability (Gott, 1973; Hillier, 1954; Smith, 1966; Smith and Burkland, 1966; Zangwill, 1967). Intact expressive ability appears limited to the use of automatic phrases, expletives, and singing

(Gott, 1973; Smith, 1966; Smith and Burkland, 1966).

The results of the hemidecorticate procedure on linguistic functions may provide limited information about normal hemispheric asymmetries, because of central nervous system abnormalities in the patient series. The findings are nevertheless important in assessing hemispheric asymmetries, because they provide information about the degree of compensation which can be attained by the intact hemisphere. In this respect, however, the data from cases of infantile hemiplegia such as Sturge-Weber-Dimitri syndrome (Dennis and Whitaker, 1977) are more valuable, since they allow the assessment of developmental aspects of cerebral organization and plasticity (Beaumont, 1983; Corballis and Morgan, 1978; Kinsbourne and Smith, 1974; Searleman, 1977).

The inferential limitations imposed by clinical investigations are similarly generalizeable to invasive procedures. Nevertheless, much valuable information has been gleaned from the application of such techniques as the sodium amytal test.

Intracarotid Sodium Amytal Procedure

The sodium amytal test (Wada, 1949), involves injecting a fast-acting barbituate (sodium amytal) into the common or internal carotid artery on one side of the neck or other in order to temporarily suppress cerebral activity ipsilaterally on the side of injection. The period of suppression, as indexed by a transitory hemiplegia contralateral to the side

of injection, lasts approximately 4 to 5 minutes (Branch, Milner, and Rasmussen, 1964). These authors have validated the method against the results of anterior temporal lobe excision. Since the drug disturbs the functioning of the cerebral hemisphere on the side of injection, the procedure has been particularly useful in evaluating the relative frequency of unilateral left, right, or bilateral speech production mechanisms in patient samples showing different manual preferences (Rasmussen and Milner, 1975). Using this technique, Rasmussen and Milner (1977) found that approximately 96% of right-handers and 70% of left or mixed-handers have speech in the left hemisphere. In contrast to this pattern, 4% of right-handers and 15% of left-handers were found to have right-hemisphere speech; only left-handers (15%) were found to have bilateral speech (Rasmussen and Milner, 1977).

Language testing during the Wada test is usually restricted to naming tasks (Millar and Whitaker, 1983). Thus, if the patient is observed to have an anomia under the drug's effects, it is generally inferred that speech processes have been disturbed in the injected hemisphere, and that the patient's speech is represented in that hemisphere. However, generalizing inferences based on the sodium amytal technique are problematic for a number of reasons. First, since the procedure is generally considered too dangerous for use in normal subjects, it is generally limited to epileptic

patients prior to neurosurgical intervention and excision of long standing epileptogenic foci. Since these patients have an established history of neuropathology and intractible seizures (Milner 1975), the functional organization of the brains of these subjects may not be appropriately representative of a normal healthy brain (Levy, 1974). The previously mentioned pitfalls of generalizing to normal subjects still apply.

Second, while the method appears elegant in allowing within-subject comparison of each hemisphere performing individually, there are a number of disadvantages to the technique proper. For example, it is uncertain how much of the drug is carried around the Circle of Willis to perfuse the hemisphere contralateral to the side of injection (Beaumont, 1983). As well, the period of cortical suppression and the testing conditions allow only the most superficial and poorly controlled investigations of cognitive functions such as speech. Furthermore, the procedure is extremely stressful for patients, which may likely interfere with their performance (Beaumont, 1983).

A more damaging criticism is that the sodium amytal technique often does not produce clear cut evidence that speech comprehension is located in the same hemisphere as speech production (Beaumont, 1983; Kinsbourne, 1971, 1974; Searleman, 1977, 1983; Wada & Rasmussen, 1960). The basis for this confound arises partly from the fact that the

intrahemispheric effects of the drug probably begin to wear-off in a posterior to anterior direction; the principle distribution of the internal carotid artery does not reach the occipital lobe, the inferior temporal lobe, and some of the medial aspects of the temporal lobe (Beaumont, 1983).

The observable effect of these sources of confound is that while a patient's dominant hemisphere for speech production is still disturbed, the patient is often quite capable of responding (non-verbally) to verbal commands (Gazzaniga, 1985). Gazzaniga reports that if a patient's left hemisphere is anesthetized with sodium amytal, and a spoon, for example, is placed in his/her left hand, the patient denies having anything placed in their left hand once the effects of the drug have passed. The mute right hemisphere is apparently unable to account verbally for occurrence of the incident. Alternatively, when the patient is tested differently; by being shown an array of objects from which to choose, the patient inevitably is able to point to the object (e.g., spoon) and then often exclaims its name with much enthusiasm (Gazzaniga, 1985). The difficulty in teasing apart the relative influence of all these sources of variance confirms the argument that the Wada test only determines the hemisphere that is specialized for speech production, and that it reveals little, if anything, about either hemisphere's ability to comprehend speech (Searleman, 1977).

Additional evidence that the sodium amytal test provides only a measure of speech production is supplied by the observation of patients having received the barbituate in the right carotid artery. Wada and Rasmussen (1960) report:

"Half the patients continued counting throughout the injection and immediately afterward, although often a few numbers at the end of the injection were poorly enunciated. The remaining patients stopped counting at the end of the injection, but resumed counting on command either immediately or after an interval of up to 20 sec., during which they seemed confused and didn't obey commands. Normal ability to name objects and normal spontaneous speech were invariably demonstrated within 30-60 sec., when the hemiplegia was still complete or nearly so." (Wada, and Rasmussen, 1960, p. 275).

The evidence clearly indicates that the sodium amytal procedure is a test of speech production, and that the procedure provides at best only an equivocal basis from which to infer hemispheric asymmetry for speech comprehension; the possible effects of the barbituate perfusing part of the contralateral hemisphere confound interpretations of speech perception.

DIRECT OBSERVATION METHODS

In some instances, the inferential limitations imposed by clinical methodologies have led a number of investigators to search for more direct tests of functional hemispheric processing which, although limited in other ways, are capable of ongoing evaluation of brain processes mediating performance on specific cognitive tasks (Bryden, 1982).

These techniques include: (1) ongoing electroencephalogram recording (EEG) (Donchin, Kutas, and McCarthy, 1977a; Donchin, McCarthy, and Kutas, 1977b; Galin, 1978; Gevins, 1983), (2) average evoked responses to stimuli (AERs) (Hink, Hillyard, and Benson, 1978; Molfese, 1979), (3) regional cerebral blood flow (rCBF) (Risberg, 1980, 1986; Carmon, Lavy, Gordon, and Portnoy, 1975; Gur and Reivich, 1980; Knopman, Rubens, Klassen, Meyer, and Niccum, 1980), and (4) positron emission tomography (PET) (Heiss, Herholz, Pawlik, Wagner, and Wienhard, 1986). Each technique has the capability of allowing the observation of hemispheric processes intermediate between input and output, and all may be used with intact subjects (Thatcher, McAlaster, Lester, Horst, and Cantor, 1983).

Electroencephalographic (EEG) Studies

Because electrophysiological variables allow the direct observation in real-time of the parallel occurrence of psychological-cognitive and physiological events, there has been a recent surge of interest in the lateral asymmetry of electrophysiological variables contingent on psychological tasks (Beaumont, 1983; Springer and Deutsch, 1981). It is generally accepted that sensory input and information processing at the cortical level can influence scalp electrode activity, and a number of EEG studies have demonstrated hemispheric asymmetries (e.g., Butler and Glass, 1974; Doyle, Ornstein, and Galin, 1974; Galin and Ornstein,

1972; Galin, Johnstone, and Herron, 1978).

Bioelectrical recordings are based on the electrical potential difference between a site of interest on the scalp and a "neutral" or "silent" area (Donchin et al., (1977a, 1977b). The spectral composition of two EEG waveforms have been of primary concern in laterality studies: (1) the high amplitude rythmical waves occuring in the 8-13 Hz frequency range, termed "alpha activity", and (2) the relatively high-frequency (13-30 Hz) low-amplitude waveform, labelled "beta activity" (Andersen and Andersson, 1968). Normally, alpha activity is prevalent when the subject is relaxed and the eyes are closed. This is usually intepreted as a sign of inhibited cortical activity in the areas found. In contrast, beta activity is usually observed in aroused, alert subjects, and is taken to indicate cortical activation (Andersen and Andersson, 1968; Bryden, 1982).

The rationale underlying EEG investigations of hemispheric asymmetry is that in most daily activities, individuals alternate between cognitive modes depending on the task demands. Thus, in a subject performing a verbal or spatial task, EEG signs of differential hemispheric activity between the active and relatively inactive hemisphere are expected in terms of the level of alpha rhythm activity (Galin and Ornstein, 1972).

A number of EEG investigations have reported greater synchronous activity in the left hemisphere (as indicated by

relatively less alpha activity) during verbal tasks, and greater relative involvement in the right hemisphere during spatial tasks (e.g., Doyle, Ornstein, and Galin, 1974; Galin, Johnstone, and Herron, 1978; Galin and Ornstein, 1972; Ornstein, Johnstone, Herron, and Swencionis, 1980). However, Gevins, Zeitlin, Doyle, Schaffer, Yingling, Callaway, and Yeager (1979) have cautioned that EEG alpha asymmetries may arise from the motor components of the task employed. EEG measures of alpha asymmetry seem subject to experimental effects and task difficulty (Bryden, 1982).

Most EEG studies have a number of methodological difficulties associated with the electrode montages used, particularly with regard to the choice of reference electrode placement, recording parameters, data analysis (including the inappropriate use of ratio scores), and the nature of the cognitive task asked of the subject (Beaumont, 1983; Donchin et al., 1977a, 1977b). Since reference electrodes placed on or near the skull usually pick-up electrical activity from the brain, and those placed elsewhere may pick-up artifacts such as heart rate or motor activity as small as eye movement, the issue of potential artifacts and their control has proven too stringent a requirement for any EEG study to meet (Beaumont, 1983). As well, substantial variation in individual anatomical asymmetries often implies that points on the scalp may not correspond directly to homologous points on the cortex of all subjects (Beaumont, 1983; Donchin et

al., 1977a, 1977b).

Thus, although the EEG procedure has provided evidence of task dependent discrepancies in alpha activity, suggesting differences in cerebral organization, it remains unclear how they are produced, and how they should be interpreted (Bryden, 1982). Consequently, asymmetries in EEG measures should be interpreted with caution.

Averaged Evoked Response (AER) Studies

Because the EEG is an overall continuous measure of brain activity, without specific reference to any particular event, it is difficult to see small changes in the EEG that relate to the occurrence of specific stimulus events; such small changes tend to be obscured by background of ongoing EEG activity (Bryden, 1982; Springer and Deutsch, 1981). However, if the same stimulus is repeatedly presented at specific points in time, and a computer is used to record the EEG waveforms during the time interval following the stimulus presentations and averages these over trials, electrical activity related to the occurrence of the stimulus may be observed. Electrical activity that is unrelated to the stimulus tends to be cancelled or averaged out over a number of trials, leaving event related potentials; the method is known as the average evoked response (AER) (Begleiter, 1979; Bryden, 1982; Desmedt, 1977a, 1977b; Lehmann and Callaway, 1979; Springer and Deutsch, 1981).

AER research has been used to investigate hemispheric asymmetries with binaurally presented auditory stimuli (Hink, Hillyard, and Benson, 1978; Molfese, 1978, 1979, 1980a, 1980b; Wood, Goff, and Day, 1971), as well as visual stimuli (Poon, Thompson, and Marsh, 1976; Ledlow, Swanson, and Kinsbourne, 1978; Rugg and Beaumont, 1978a, 1978b). Studies employing binaural stimulus presentation have found a robust right ear effect indicating that specific components of the auditory AER are attention (Hink et al., 1978) and task demands (Hink et al., 1978; Wood, et al., 1971). As well, Molfese (1979) demonstrated that both the left and right hemispheres show responses that distinguish between meaningful and nonsense sounds, and even isolated one component that suggests a subcortical contribution to semantic processing.

The determination of hemispheric asymmetries for visual stimuli has proven relatively difficult to accomplish, because of the difficulty in determining appropriate tasks (Bryden, 1982). However, Buchsbaum and Fedio (1969) have demonstrated that AERs elicited by both verbal and nonverbal stimuli were more distinct and had shorter latencies from left-hemisphere recording sites. Like the study of Wood et al., (1971), this finding provides additional evidence of task-dependent asymmetry. Rugg and Beaumont (1978b), however, could not provide a clear replication of this

finding. They found that the AER waveform latency to be shorter over the right hemisphere than the left for both verbal and nonverbal stimuli, and that waveform amplitude was greater over both hemispheres during a letter task than during a visuospatial task. The authors concluded that the right hemisphere is preeminent in the early stages of cognitive processing. Additional evidence for task-dependent hemispheric differences were reported by Ledlow, Swanson, and Kinsbourne (1978). Their subjects were asked to identify letter pairs that were either physically identical or identical in name only. Significant task by hemisphere interactions were found, and the left-hemisphere amplitudes were smaller for different case pairs than for same-case pairs, whereas the reverse was true for the right hemisphere.

Additional evidence that hemispheric asymmetries may be task-dependent has been provided by Papanicolaou (1980) who had subjects perform a detection task based on semantic, phonetic, or acoustic cues. Recordings were made as subjects monitored a word list and signalled the presence of words containing a particular stop consonant, a particular category of word, or a particular acoustic change, such as intensity. The same word lists were used for each of the detection instructions and for a control condition, which required no response. The dependent measure was waveform amplitude. As compared to the control condition, the waveform amplitude decreased in the left hemisphere and increased in the right

hemisphere for both phonetic and semantic tasks, but remained essentially unchanged for the acoustic detection task. These results suggest that activation of the left hemisphere, as indicated by a reduction of waveform amplitude, may inhibit input information to the right hemisphere, as indicated by the enhanced waveform amplitude (Bryden, 1982; Papanicolaou, 1980). Although these findings tend to provide substantial evidence for task-dependent hemispheric differences, the significance of the findings is problematic to assess because of methodological difficulties.

Studies of AERs have many of the same difficulties as those of on-going EEG and many of the cautions applicable to EEG research are also pertinent to AER studies (Beaumont, 1983; Bryden, 1982). The field is plagued by methodological debates about reference electrode sites, artifact rejection, assumptions which underlie the averaging process, measurement techniques, inappropriate statistical analyses, the effects of differential skull thickness on surface electrodes, the control of cognitive set and subject strategies, and the use of stimuli that may be of little significance in understanding the nature of functional cerebral asymmetry (Begleiter, 1979; Bryden, 1982; Desmedt, 1977a, 1977b; Lehmann and Callaway, 1979; Rugg, 1982; Springer and Deutsch, 1981).

Thus, although the AER literature has demonstrated that task-dependent asymmetries exist, it is also marked by

inconsistency in results and a diversity of approaches and analytic procedures (Bryden, 1982). The inadequacy of both the cognitive models used and the general understanding of the electrophysiological phenomena limit the rigorous testing of crucial predictions and the interpretation of data (Beaumont, 1983; Bryden, 1982).

Regional Cerebral Blood Flow (rCBF) Studies

Because local increases in the blood-flow in the brain indicate increased metabolic activity, and are very sensitive and responsive to minute changes in cellular activity, the measurement of regional cerebral blood-flow (rCBF) allows direct correlational observations of localized neural activity within various areas of either hemisphere (Ingvar and Risberg, 1967; Lassen and Ingvar, 1961; Raichle, Grubb, Gado, Eichling, Ter-Pogossian, 1976).

In practice, the method is relatively simple. The standard procedure calls for the inhalation of a mixture of air and inert radioactive ^{133}Xe (Xenon) gas for one minute, followed by 10 minutes of normal breathing. The arrival and disappearance of the inert radioactive tracer is usually monitored by bilaterally placed scintillation detectors at the surface of the head. An estimate can then be made of local blood-flow within a few minutes (Risberg, 1980, Risberg, 1986). Presently available commercial systems have 16 or 32 detectors, which tends to give a rather coarse spatial resolution of 3-5 cm (Risberg, 1986; Beaumont, 1983).

Alternatively, cortical blood-flow may be calculated from recorded curves when the method of choice is the intracarotid injection of the tracer (Risberg, 1986). The intra-arterial method provides superior spatial resolution, but is invasive and usually reserved for patient series.

The basic advantages of the standard inhalation method are: (1) that it allows the observation of a physiologic phenomenon that mirrors the functional state of the brain, and which may be measured with great accuracy; (2) the spatial resolution is better than for most other measures of brain activity (e.g., EEG recordings) and is improving with recent advances; (3) repeated measurements can be made safely in normal healthy volunteers or patients; and (4) the procedure is relatively inexpensive and efficient. The method has great promise and is likely to be an important aid in future investigations of differential hemispheric asymmetries related to cognitive processes in health and disease (Beaumont, 1983; Risberg, 1986).

A major disadvantage in utilizing the procedure is that present rCBF technical systems give fairly coarse images of the flow pattern, because of the limited number of detectors. However, recently reported technological improvements, allowing as many as 254 mini-detectors should improve spatial resolution to approximately 10 mm, approaching the high-resolution of intra-arterial systems (Risberg, 1986). The higher resolution should improve the accuracy of flow

maps and allow more definite conclusions regarding differential hemispheric activity on various cognitive tasks. Temporal resolution may also be improved by utilizing tracers with very short physical half-lives, possibly allowing flow determinations every minute (Risberg, 1986). Such improvements in rCBF methodology will likely open new possibilities for studying the dynamic hemispheric asymmetries in cortical information processing. Technical advancements may not, however, adequately compensate for methodological oversights such as using single detector arrays on the left or right of the head in separate recording periods; this is less satisfactory than simultaneous bilateral recording (Beaumont, 1983). Furthermore, it may prove difficult to arrive at satisfactory control over the non-cognitive components of task performance, which may confound the sensitive blood-flow measures. Also, if task involvement is to be monitored and performance assessed, considerable care needs to be taken that response related artifacts, and more general activities that are not task-specific, do not introduce unwanted variance into the results (Beaumont, 1983).

The results of numerous studies employing the rCBF measures during various physical and cognitive tasks have been impressive. The most striking patterns of blood-flow have been based on anterior to posterior differences across the whole brain, but differences between the hemispheres have

also been reported (Springer and Deutsch, 1981; Risberg, Halsey, Wills, and Wilson, 1975).

In a passive listening task that required subjects to listen to verbal or musical material, Carmon, Lavy, Gordon, and Portnoy (1975) monitored rCBF. They found that while subjects listened to music, blood-flow increased in the right hemisphere, and while subjects listened to verbal material, blood-flow increased in the left hemisphere. However, Knopman, Rubens, Klassen, Meyer, and Niccum (1980) were unable to replicate this finding. In fact, they reported that whether or not subjects listened to verbal or nonverbal material blood-flow increased in the left hemisphere. However, their nonverbal task may have been inappropriate to elicit right-hemisphere activity since it involved listening for changes in stimulus intensity (Bryden, 1982).

Using simultaneous bilateral recordings of rCBF, Risberg, et al., (1975) compared blood-flow patterns of right handed male volunteers during a verbal analogies test and on a test of perceptual "closure"; the closure task required subjects to view incomplete hand drawings and intuit what the drawing represented. Small, but statistically significant effects were found in the predicted direction; the subjects showed an increase in mean left-hemisphere flow during the verbal analogies test, and an increase in mean right-hemisphere flow during the picture completion task. Risberg and colleagues (1975) computed for each task, the

intrahemispheric regional contributions to the interhemispheric blood-flow differences; the largest differences were found in the frontal, fronto-temporal, and parietal regions for the verbal tests. Gur and Reivich (1980) have also reported significant increases in left-hemisphere blood-flow measures during a verbal analogies task, but non-significant increases in right-hemisphere blood-flow on a picture completion task.

In response to such apparently clear evidence in favor of hemispheric differences for verbal tasks, Lassen, Ingvar, and Skinhoj (1978) have cautioned against overly simplistic interpretations, and emphasized that the most impressive aspect of rCBF studies is the striking similarity in the blood-flow patterns in the two sides of the brain (especially in homologous structures) during such lateralized activities as speech. Apparently, complex tasks may typically involve increased patterns of bi-hemispheric, as well as intrahemispheric activation.

Positron Emission Tomography (PET) Studies

Because glucose consumption is the most important energy-supplying metabolic process related to cortical activity, changes in functional activity may be detected with this metabolic variable by a new radioisotope diagnostic tool, positron emission tomography (PET) (Heiss et al., 1986). The procedure is rather complex. Concentrations of radioactive materials are tagged to selected chemicals and

are injected intravenously. Counts of localized radioactivity concentrations are transformed according to biomathematical formulae and represented as images similar to, but with substantially higher resolution than tomographic slices provided by the x-ray CT. The composite images represent a three-dimensional quantification, pixel by pixel, of the regional glucose metabolic activity of the scanned brain slices (Cummings and Benson, 1983; Heiss et al., 1986). PET measurements of local glucose consumption are widely used in functional studies on normal volunteers (Heiss et al., 1986).

Increases in local glucose metabolism have been demonstrated during functional activation of the corresponding brain structures (Greenberg, Reivich, Alavi, Hand, Rosenquist, Rintelmann, Stein, Tusa, Dann, Christman, Fowler, MacGregor, and Wolf, 1981; Phelps, Mazziotta, and Huang, 1982). Visual stimuli have been shown to elicit metabolic rate rises in the primary visual cortex with increases and spreading metabolic activation being significantly related to stimulus complexity (Phelps, Kuhl, and Mazziotta, 1981). Verbal stimulation has been shown to result in particularly strong metabolic activity in the left hemisphere (Heiss et al., 1986). In contrast to this pattern, musical stimulation has been shown to elicit increased metabolic activity in the right hemisphere of musically naive subjects, but increased metabolic activity in

the left hemisphere of musically sophisticated subjects (Heiss et al., 1986). Although these findings are impressive, the PET procedure is not without drawbacks.

Despite its obvious advantages, there are a number of disadvantages associated with PET methodology. With auditory stimulation, patterns of glucose metabolism may vary depending on the modality of stimulation and/or individual subject strategies of interpretation (Mazziota, Phelps, Carson, and Kuhl, 1982). Also, the effects of nuisance sensory stimulation can contribute to artifacts, which may be difficult to tease apart from the effects of the target stimulation. As well, increases in glucose metabolic rates tend to be dependent on stimulus intensity (Heiss et al., 1986). Finally, a major disadvantage of PET studies is the prohibitive cost associated with the production of positron-emitting ions, which demands the use of a cyclotron. Consequently, only a limited number of research centers can perform this procedure. The contribution yet to be made by the superior spatial and temporal resolution provided by nuclear medicine procedures such as PET and magnetic resonance imaging (MRI) may be delayed considerably because the methods may prove excessively expensive for most research enterprises (Beaumont, 1983; Cummings and Benson, 1983).

Because of the exorbitant costs associated with such highly technical direct-observation methods, the procedures have often been reserved for clinical investigations that

could simultaneously meet the diagnostic needs of patient populations. Consequently, the vast majority of research on functional human hemispheric asymmetries with normal subjects has been largely restricted to less expensive techniques such as tympanic membrane temperature, tactile stimulation, visual half-field presentations, and dichotic listening. Careful consideration should be given to the potential for systematic error inherent in the divisive pattern of pairing specific populations with specific procedures. Practical realities restrict the generalizeability of findings. However, some techniques (e.g., EEG, AER, etc.) are applied as much in studies involving normal subjects as those involving patients with atypical brain organization.

Tympanic Temperature Studies

A rarely used indirect measure of cerebral blood flow may be obtained from eardrum temperature (Beaumont, 1983; Dabbs, 1980; Meiners and Dabbs, 1977; Hancock and Dirkin, 1982; Holt and Brainard, 1976; Swift and Perlman, 1985). The procedure is derived from the observation that changes in volume of cerebral blood flow may be monitored through fluctuations in brain temperature as well as through infusions of radioactive material (Dabbs, 1980; Meiners and Dabbs, 1977; Swift and Perlman, 1985). The method involves the use of tympanic thermometers to monitor brain temperature. It exploits the well known relationship between ear-canal temperature and brain temperature (Cooper,

Cranston, and Snell, 1965). The examiner may record differences between hemispheric temperatures of subjects at rest and show how these differences are related to variations in the volume of cerebral blood flow received by each hemisphere (Dabbs, 1980; Swift and Perlman, 1985).

The procedure is relatively simple, inexpensive, painless for subjects, and allows the experimenter to monitor hemispheric activity continuously throughout a cognitive task (Dabbs, 1980; Swift and Perlman, 1985). Using the method, Swift and Perlman (1985) have reported interesting observations of hemispheric asymmetries on verbal and nonverbal visual discrimination tasks. Subjects were fitted with tympanic temperature sensors bilaterally, which allowed the measurement of blood flow during the verbal and nonverbal tasks. The verbal task required subjects to view an array of three pronounceable nonwords for 3 seconds and thereafter indicate by a "yes" "no" key-press, if any one of the six individually presented choices of similar non-words corresponded to any one of the three initial targets. The nonverbal task involved photographs and followed a similar procedure. Four measures were taken on each subject: mean temperature, hemispheric bias (i.e., mean left ear fluctuation minus mean right ear fluctuation), accuracy, and learning effects. Verbal tasks could not elicit a left-hemisphere bias in tympanic temperature. However, a significant right-hemisphere bias in tympanic temperature was

elicited by the nonverbal task. Subjects also were more accurate when the right hemisphere showed relatively higher temperatures. Although the right-hemisphere findings are consistent with previous reports of right-hemisphere superiority for the processing of complex visual stimuli (Gazzaniga, 1970), the left-hemisphere data are not. The authors explained the absence of a left-hemisphere effect as possibly due to subject strategies. Swift and Perlman's (1985) data appear somewhat at odds with those of Knopman et al., (1980) who found left-hemisphere increases in blood flow (using a rCBF method) for both verbal and nonverbal material in an auditory monitoring task. Such instances of discrepant findings tend to highlight the importance of methodological issues in hemispheric asymmetry investigations.

Although the tympanic temperature method offers researchers an inexpensive method to monitor hemispheric activity throughout an entire task, it also appears as subject to many of the previously cited methodological pitfalls as its alternatives. In particular, the procedure may be sensitive to artifact, subject strategies, and stimulus characteristics such as intensity. As well, the method is relatively insensitive to intrahemispheric differences in blood flow, while individual variations in skull structure and underlying brain tissue introduce considerable random error, which reduces the meaningfulness of measures. However, the utility of this new method may

become apparent when it is used in conjunction with other techniques.

INDIRECT OBSERVATION METHODS

Tactual Laterality Studies

When compared to other investigative techniques such as visual and auditory methods, somesthetic laterality experiments have not been as popular nor as refined. Somesthetic laterality experiments have been based on the rationale that the crossed representation of somatosensory system should provide right-sided advantages for verbal tasks if such tasks elicit greater left-hemisphere involvement, and left-sided advantages for nonverbal tasks if they elicit greater right-hemisphere involvement (Bryden, 1982). In a review of somatosensory research, Corkin (1978) concluded that there is no evidence for any lateralization effect in basic somatosensory measures (e.g., pressure sensitivity). Bryden (1982) explained this lack of evidence as a function of the rather simple tasks used, and suggested that to elicit somatosensory effects related to hemispheric asymmetries requires more complex verbal and nonverbal tasks. Task complexity has been found to contribute substantially to laterality scores (Mohr and Costa, 1985).

Using this line of reasoning, a number of authors have reported left-hand superiority for reading Braille letters (Hermelin, and O'Connor, 1971; Rudel, Denckla, and Hirsch,

1977; Smith, Chu, and Edmonston, 1977). Left-hand superiority effects have also been reported for tactual determination of direction (Benton, Levin, and Varney, 1973), tactile matching (Benton, Varney, and Hamsher, 1978), and tactile form recognition (Dodds, 1978). To date, most reports of verbally related unimanual tactile tasks indicate right-hemisphere superiority (Bryden, 1982).

In a novel dichhaptic paradigm, Witelson (1974, 1976a) found a clear left-hand advantage for tactile form recognition, and a clear right-hand advantage for letter recognition. In a later study, Witelson (1976b) found that left-hand advantage for haptic form was not apparent in girls until age 12. However, attempts to replicate Witelson's form data have been unsuccessful. Cranney and Ashton (1980) have reported right-hand superiority at most ages regardless of hand dominance. Bryden (1982) explains these equivocal findings as a function of individual subject strategies for coping with the task, attention factors, order of report when more than one stimulus pair has been presented dichhaptically, and possible biases for reporting certain shapes over others.

Some attempts have been made to address these issues; for example, Oscar-Berman, Rehbein, Porfert, and Goodglass (1978) found order-of-report laterality effects for the second hand reported but not the first. Another attempt to control contributing laterality effects was undertaken by

Gardner, English, Flannery, Hartnett, McCormick, and Wilhelmy (1977). They found stimulus-response compatibility effects; responses were faster with the right hand when the stimuli were presented to the right hand, which suggests that such effects may obscure hemispheric asymmetries (Bryden, 1982). In an elegant study, Nachshon and Carmon (1975) have provided data indicating a particular pattern of hemispheric asymmetry for spatial and sequential tasks that may only be observed under conditions of stimulus competition; a left hand advantage on spatial tasks and a right hand advantage on sequential tasks. With unimanual stimulus presentations, the pattern was reversed. This finding may account for reports of left-hand superiority on unimanual verbal tasks. However, it does not provide an explanation for why such effects might occur.

The many problems associated with somatosensory investigations of hemispheric asymmetry have yet to be resolved. To date, the behavioral measures provided by dichhaptic research are too inconclusive to provide reliable indices of any functional hemispheric asymmetries (Bryden, 1982; Witelson, 1976a).

Visual Laterality Studies

Vision has proven to be the most popular modality for investigating hemispheric asymmetries (Bryden, 1982). This popularity may be accounted for by the fact that under the appropriate conditions, it is relatively simple to present

stimuli uniquely to one or the other hemisphere. This may be achieved because the visual system is so constructed that stimuli presented to the right visual field have their cortical representation in the left occipital cortex whereas stimuli presented to the left visual field have their cortical representation in the right occipital cortex. This state of affairs allows the investigator to observe the effects of presenting verbal material to either hemisphere, and based on the subject's performance, to indirectly infer differential hemispheric asymmetries on various tasks. Lateralizing stimuli to one visual field or the other may be accomplished by presenting the stimuli so briefly that the eyes do not have the time to move from one location to another during stimulus exposure (Bryden, 1982). Woodworth (1938) has provided evidence indicating that approximately 180 msec are needed to initiate saccadic eye movements. Presenting the visual stimuli with a tachistoscope ensures rapid, controlled exposure durations of 100 msec or less and results in negligible eye movement during exposure (Bryden, 1982). The stimuli may be presented unilaterally (i.e., to one visual field) or bilaterally, as well as monoptically or dichoptically. Alternative procedures such as fixing the stimulus image on a contact lens system (Pritchard, Heron, and Hebb, 1960) so that when the eye moves the retinal image moves also, have proven somewhat too complex to have gained wide popularity (Bryden, 1982).

Generally, the majority of tachistoscopic studies that have presented stimuli unilaterally or bilaterally have reported evidence in support of the classic left-right hemisphere dichotomy; a right visual field advantage tends to be elicited by words and letters while a left visual field advantage is elicited on tasks that do not involve language (Bryden, 1982). Bilateral presentation paradigms involving linguistic material such as words generally produce more robust effects than unilateral presentation procedures (Bryden, 1982; Kershner, and Jeng, 1972; Hines, 1976).

Hines (1975) has provided an interesting conceptual argument to account for the greater asymmetries found in bilateral stimulus presentation paradigms. His argument is based on the notion that bilateral stimulus presentation tends to stimulate both hemispheres, whereas unilateral stimulus presentation tends to stimulate the bi-hemispheric transfer of information. Hines (1975) maintains that unilateral presentation of a stimulus creates a situation in which the hemisphere that is more specialized or efficient at processing the stimulus will always initiate efforts to carry out the task. He also proposes that while the unilateral stimulus presentation procedure is more appropriate for assessing the efficiency of interhemispheric transfer of information (e.g., in terms of transmission time), the bilateral stimulus presentation procedure inhibits interhemispheric communication, and as such, is a superior

method for assessing the capacity of each hemisphere to deal with the task. Bryden (1982) has suggested that if perceptual confusion is the critical aspect of stimulus competition paradigms, the use of unilateral stimulus presentation and binocular rivalry may be more appropriate than the use of bilateral stimulus presentation. Thus, the presentation of two different stimuli within the same visual field could produce the perceptual competition required for true dichoptic stimulation. Bryden's (1982) insightful suggestion presents exciting possibilities. However, to this writer's knowledge, no studies using such a paradigm have yet been published.

Discrepant performance patterns in relation to handedness have often been reported, suggesting that some component of both unilateral and bilateral presentations is related to cerebral speech lateralization (Bryden, 1982). However, differences between left-handed and right-handed subjects are not always evident (Goodglass and Barton, 1963). Furthermore, the classical pattern of hemispheric asymmetry for language is often inconsistent in left-handers (Bryden, 1965, 1982; Haun, 1978).

On a more practical level, there are a number of methodological problems associated with the tachistoscopic technique. The adequacy of any tachistoscopic stimulus presentation procedure is dependent on how successful it is at controlling fixation (Heron, 1957; Bryden, 1970, 1982).

As well, the unilateral presentation of linguistic material, involving one stimulus only, may not produce the same results as the bilateral presentation of dichoptic material.

However, this enhanced right-visual-field effect may be due to factors unrelated to hemispheric specialization (Bryden, 1982). The bilateral approach seems particularly subject to difficulties in fixation control (Heron, 1957), attention strategies, and order of report effects (Bryden, 1982). This point would seem especially pertinent if more than one pair of stimuli are presented serially, which would also tend to introduce short-term memory confounds. Also, the alignment of the stimulus word has been shown to influence the measure of hemispheric asymmetry. A number of investigators have reported larger asymmetries in favor of the right-visual-field when words are aligned horizontally than when they are aligned vertically (Mackaver, Curcio, and Rosen, 1975; McKeever and Gill, 1972). An additional complication is introduced when the examiner attempts to control central fixation by requiring subjects to report the pre-target fixation stimulus. Apparently, the type of stimulus used to control fixation can produce priming effects that influence not only the degree but also the direction of the visual-field superiority on linguistic tasks. Right visual-field effects have been reported when a number is used to control central fixation (McKeever and Huling, 1971), whereas left visual-effects have been reported when a

geometric form is used (Kershner et al., 1977). Cleverly designed experiments can, however, overcome some of these difficulties; for example, Piazza (1980) managed to control for the priming effect of fixation control stimulus, as well as order-of-report strategies, by using an arrowhead pointing either left or right, which also cued which visual field was to be reported. Presumably, the use of an arrowhead as a fixation control stimulus requires relatively low levels of processing and does not confound with the observed asymmetry on the task. Although such ingenious strategies provide solutions to some of the problems with the tachistoscopic procedure, there are even more serious issues to deal with.

The choice of dependent measure used may be of considerable relevance in the determination of any hemispheric asymmetries. Most studies have compared accuracy in the two visual fields, but accuracy measures are relatively insensitive to small effects (Bryden, 1982). As an alternative, resource oriented dependent measures such as reaction time (RT) may be used (Cohen, 1973; Klatzky 1970; Moscovitch, 1979). The use of RT, however, introduces questions regarding the interpretation of extremes in performance variability (Graves and Morley, 1986). Furthermore, since RT paradigms have been developed to assess the resource limitations of subjects (Norman and Bobrow, 1975); that is, to determine how quickly a subject can perform a task, given a clearly visible stimulus, the

application of RT measures in visual laterality experiments may be inadequate. The basis for this inadequacy rests in the fact that tachistoscopic studies require the rapid exposure of stimulus material to control saccadic eye movement. The task places considerable limitations on the data. Therefore, it may not be appropriate to apply such resource-oriented measures to data-limited tasks (Bryden, 1982).

A most damaging shortcoming of most visual laterality experiments is that they require a verbal identification of the stimulus. Bryden (1982) has outlined this shortcoming elegantly:

"Verbal responses, whether timed or simply used to indicate accuracy, involve left-hemispheric speech output mechanisms, and somehow the information must reach these systems. There is thus an intrinsic left-hemisphere bias in verbal response procedures." (Bryden, 1982, p. 25).

A number of researchers share Bryden's (1982) view that verbal mode of response tends to bias measures in favor of the left hemisphere (Beaumont, 1983; Kinsbourne, 1974; Levy 1974; Searleman, 1977, 1983). The use of a verbal mode of response may also tend to suppress any observable left-visual-field (LVF) effects suggestive of right-hemisphere speech capabilities. The natural consequence would then be to infer that speech processes are localized in the left hemisphere only. Thus, it may be inappropriate to infer speech perception on the basis of a subject's performance when the dependent measure of such performance is speech

production. Evidently, right-visual-field (RVF) effects will not necessarily appear simply because verbal stimuli have been presented. The presence of RVF effects will depend on the nature of the task being performed by the subject; more specifically, performance will depend on the task demands placed on the subject. This definition encompasses not only response-mode bias, but also its effects in conjunction with the stimulus characteristics. Thus, when a subject is required to respond verbally on a linguistic task, the mode of response may very likely prime the left hemisphere and also interact with the stimulus material to produce compounded left-hemisphere bias. The observable effects of such a bias would tend to be substantially greater RVF effects. This state of affairs may account for many reports of visual laterality effects purported to demonstrate left-hemisphere dominance on linguistic tasks (McKeever and Huling, 1971; McKeever and Gill, 1972; White, 1969).

The importance of stimulus characteristics as contributing to the degree, and in some instances, the direction of hemispheric asymmetry for speech has been emphasized in a number of reports (Bradshaw and Gates, 1978; Bryden and Ley, 1983; Colthart, 1983; Day, 1977, 1979; Ellis and Shepherd, 1974; Hines, 1976, 1977; Searleman, 1983; Studdert-Kennedy and Shankweiler, 1970). Clinical investigations have reported that highly imageable stimuli such as concrete nouns, tend to elicit LVF effects whereas

abstract nouns and/or verbs tend to elicit RVF effects (Ellis and Shepherd, 1974; Gazzaniga, 1970). Similar results were reported by Marcel and Patterson (1978) who found that word imageability affected LVF but not RVF presentation. Attempts to replicate these findings have met with mixed results. Ornstein and Meighan (1976) found a LVF superiority with both abstract and concrete nouns in a literal replication of the Ellis and Shepherd (1974) paradigm, while Hines (1976) obtained results similar to those reported by Ellis and Shepherd (1974), but only for high frequency words. Bradshaw, Nettleton, and Taylor (1981) found differential asymmetries for abstract and concrete nouns, but their paradigm also also confounded frequency; abstract words were all of low frequency of occurrence in the language, while concrete words were all of high frequency of occurrence in the language.

Investigations with normal subjects have also provided evidence of right-hemisphere speech capabilities. Hines (1976, 1977), and Day (1977) have reported LVF effects for concrete or high imagery words. However, other related studies failed to replicate these results (Ornstein and Meighan, 1976; McFarland, and Ashton, 1978; Moscovitch, 1983; Schmuller and Goodman, 1979).

Moscovitch (1983) reported that he was unable to replicate Day's (1977, 1979) finding of consistent left-field advantage only for abstract words in a lexical decision task.

In his investigation, Moscovitch (1983) found a right-field (i.e., left-hemisphere) advantage for concrete as well as abstract words. However, his data were inconclusive; concrete words produced smaller perceptual asymmetries than did abstract words, and statistically, only the overall right-field advantage was significant. Moscovitch (1983) also reported that subjects distinguished between words and nonwords by responding with either the left or right hand when a word appeared. Thus, his failure to replicate Day's (1977, 1979) findings may have been due to failure to control for hand responding. If Moscovitch's (1983) subjects consistently responded with their right hands, it may have induced a right-eye (i.e., left-visual field) bias in attention (Bryden, 1982).

On a more general level, Bryden and Ley (1983) have provided a possible explanation for the variability in results reported from tachistoscopic paradigms. Drawing from Zajonc's (1980) hypothesis that affective responses to stimuli have an immediacy and potency that allows affect to be registered in the absence of cognitive awareness of the stimulus, Bryden and Ley (1983) have suggested that right-hemisphere linguistic processes may be activated at an unconscious level where one need not be aware of the specific word; for example, Day's (1977) lexical decision task. In contrast, on a word recognition task, such as the one used by Schmuller and Goodman (1979) one might fail to find an

imagery effect, because specific words need to be identified (Bryden and Ley, 1983).

In a review of both clinical studies and investigations of right-hemisphere language in normal subjects, Bradshaw (1980) concluded that the right hemisphere has access to concrete or imageable words and to high frequency words, whereas the left hemisphere appears better suited for the analysis and interpretation of abstract or non-imageable words and to low frequency words.

Bryden and Ley (1983), and Moscovitch, (1983) have suggested that right-hemisphere language functions may be mediated by the emotional, as well as, by the imageable attributes of words. In light of reported evidence suggesting that the right hemisphere plays a significant role in the processing of emotional information (Borod, Koff, and Caron, 1983; Bryden, 1982; Moscovitch, 1983; Searleman, 1983), the hypothesis seems valid. Evidence in support of the hypothesis has been provided by Graves, Landis, and Goodglass (1981). They have reported findings which suggest that emotional words are a more important determinant of recognition in the LVF than in the RVF. Aside from the likelihood that the right hemisphere plays an important role in the mediation of certain stimulus types, there are additional methodological issues which may account for inconsistent reports of RVF superiority with linguistic material.

Variations in level of control over task demands (i.e., stimulus material and mode of response) may also account for the fact that tachistoscopic paradigms typically show a RVF advantage in approximately only 70% of right-handers (Kinsbourne, 1974; Levy, 1974; Searleman, 1977). These estimates are substantially discrepant with estimates from clinical populations, which have indicated that 95% to 99% of right-handers are left-hemisphere dominant for speech (Blumstein, Goodglass, and Tartter, 1975; Levy, 1974; Rasmussen and Milner, 1977).

An alternative explanation for such discrepancies is that the clinical estimates, which have been derived principally from two sources; the computation of aphasics with left as opposed to right-hemisphere damage, and the performance of patients under the influence of sodium amytal, may also be erroneous. Like the majority of studies investigating lateralized speech in normal subjects, the clinical investigations have relied principally on the ability of their subjects to respond verbally to linguistic stimuli. However, unlike most clinical studies, investigations with normal subjects have required greater involvement of speech comprehension functions since they are usually based on visual sensory field techniques. Thus, if the clinical estimates of speech dominance have been based on measures which introduced a left-hemisphere bias (i.e., verbal responses), it is conceivable that these clinical

estimates might also reflect to a certain extent, spuriously inflated estimates of left-hemisphere linguistic superiority. Consequently, if these "criterion" estimates are in error, it would seem only natural that the findings from investigations with normal subjects would regularly fall short of these estimates. The principle reason for this would be that visual laterality tasks measure not only speech production functions, but also speech perception functions (Searleman, 1977).

Still another explanation may be that extremes in degree of lateralized function may in fact reflect abnormal brain organization. Thus, if the high degree of lateralization for speech production, as evidenced in clinical populations, does indeed reflect highly lateralized speech functions in general (i.e., speech production as well as speech perception), then perhaps the cerebral organization underlying the extremely lateralized functions so often observed in clinical studies is more representative of abnormal brain functioning than it is of normal brain functioning. If this were the case, it would explain why investigations with normal subjects are generally unable to produce the sort of clear cut hemispheric asymmetries that are typically reported with patient series.

As Luria (1966) and LeDoux (1983) have argued, psychological processes are complex and not localized in either hemisphere, but rather, they reflect bi-hemispheric integration. Along this line of reasoning, if this type of

bi-hemispheric integration represented normal brain functioning, and by implication, normal cerebral organization, then perhaps abnormal brain functioning, such as extremes in degree of lateralization so often observed in brain damaged patients, reflects abnormal bi-hemispheric integration. The notion presents an interesting inferential problem and suggests a somewhat unorthodox perspective from which to address hemispheric asymmetry issues.

From this cursory review of tachistoscopic paradigms, it is apparent that although verbal laterality effects are at least partly dependent on the specialized linguistic functions of the left hemisphere, the method is problematic because of difficulties in teasing apart functional asymmetry effects from extraneous factors. Consequently, sweeping generalizations regarding left-hemisphere dominance for speech processing would appear inappropriate when based on data derived from tachistoscopic paradigms. However, broad generalizations regarding left-hemisphere dominance for speech have been much more common in reports using the dichotic listening (DL) paradigm.

Dichotic Listening Studies

Berent (1981) has suggested that if we are to develop a deeper understanding of normal brain-behavior relationships, there is a need for continuing studies of hemispheric functions in populations other than those with neuropathological impairment. Toward this end, Doreen Kimura

(1961a, 1961b, 1964, 1967, 1968, 1973) has for a number of years been involved in expanding non-invasive methods such as the dichotic listening (DL) procedure for investigating the asymmetry of hemispheric functions in neurologically normal subjects. The DL procedure used by Kimura is a modification of the dichotic listening technique originally devised by Broadbent (1954, 1956, 1958).

Since Broadbent's initial reports, the procedure has been used extensively for a variety of purposes (Bryden, 1962, 1963, 1967, 1969, 1982). However, it is the technique's application to the study of hemispheric asymmetries in brain damaged (Gordon, 1974, 1975; Kimura, 1961a, 1961b), as well as, normal subjects (Gordon 1974; Kimura, 1961a, 1961b, 1964, 1967, 1968, 1973; King & Kimura, 1972), that has generated the most interest and controversy.

Typically, the technique involves the simultaneous presentation of a spoken digit to one ear, and a different spoken digit to the other ear via stereophonic headphones. Three such pairs are usually delivered in sequence at fixed intervals of 1/2, 1, or 2 seconds during one trial. The subject may be asked to report all the stimuli freely or according to specific instructions, depending on the dimension being investigated (Broadbent, 1957a; Bryden, 1964; Inglis, 1965; Kimura, 1961a, 1961b, 1973; Treisman, 1964a, 1964b). The stimuli may be varied such that words (i.e., Caplan, Holmes, & Marshall, 1974; Curry, 1967), syllables

(Studdert-Kennedy & Shankweiler, 1970), tones (Spreen, Spellacy, & Reid, 1970), or melodies (Kimura, 1964) are used (Mohr, 1982). Accuracy (the number of correct reports) is the basic dependent variable. The difference score (number of correct right-ear responses minus the number of correct left-ear responses, or R-L) is generally used as the laterality index or measure of underlying hemispheric asymmetry for speech (Kimura, 1961a). An equally common procedure is to normalize the difference score as $(R-L)/(R+L)$, which creates a mathematical ordinal scale that allows the analysis of variance of group data (Bryden, 1963, 1969). The transformation also tends to make the laterality index less dependent on the number of trials and overall accuracy (Bryden, 1982). Marshall, Caplan, and Holmes (1975) and Repp (1977) have proposed a third, more complex transformation of the data ("e"), which reportedly avoids some of the mathematical limitations of the two simpler laterality indices. With a number of transformations available, the issue of selecting one method over the others becomes problematic with regard to the derivation of a laterality index.

Graves and Morley (1986) have demonstrated that depending on the transformation used for such accuracy data, the laterality index may be interpreted differently. Table 1 shows fictitious data in which subject 3 shows the largest ear asymmetry using one index, but the smallest ear asymmetry

Table 1

Fictitious Dichotic Listening Data.

Subject	Accuracy		Index of Laterality		
	Right Ear	Left Ear	R-L (Order)	(R-L)/(R+L) (Order)	e (Order)
1	60	51	+9 (1)	+.081 (2)	+.101 (2)
2	80	72	+8 (2)	+.053 (3)	+.167 (1)
3	40	33	+7 (3)	+.096 (1)	+.096 (3)

(Graves & Morley, 1985)

using another. Such problems generally arise from varying overall accuracy (Graves & Morley, 1986). They reflect the real limitations of mathematically transforming nominal scale data into ordinal scale data when the true ordering of subjects is undetermined due to measurement inadequacy. The fact that all three transformations show agreement as to the direction of ear asymmetry, but not degree attests to this fact. Furthermore, maintaining accuracy at 100% and making reaction time (RT) the dependent measure does not resolve the difficulty. If the fictitious raw data in Table 1 are multiplied by 10 to produce fictitious RT's, the same discrepant ordering of subjects is apparent in the first two indices. As Graves and Morley (1986) report, the basic problem becomes one of varying overall performance rather than varying overall accuracy. If one is attempting to compare the degree of hemispheric asymmetries among different subjects or stimuli, which requires at least an ordinal scale of measurement, the question then becomes one of determining the theoretical grounds for choosing or validating any index in particular (Graves & Morley, 1986). As Richardson (1976) and Colbourn (1978) have suggested, this requires a theoretical understanding of the mechanism which produces the observed asymmetries.

Bryden's extensive review of the DL literature (1967, 1982) suggests that in the absence of any absolute knowledge of the functional mechanisms underlying cerebral asymmetry,

it may be necessary to make the assumption that the magnitude of observed ear asymmetry in favor of the right ear represents greater dependence on the left hemisphere for speech processing. With this working assumption, it is possible to examine current DL models of the mechanism of hemispheric asymmetry, and determine if the methodology purported to demonstrate the validity of the models is adequate. Furthermore, if one is interested in comparing the degree of lateralization across subjects or conditions, then the methodology should not allow overall performance to vary in a way to cause the choice of transformation to affect the ordering (Graves and Morley, 1986). A number of working models have been proposed to account for the mechanism underlying the dichotic listening effect (Mohr, 1982). However, upon scrutiny, it becomes apparent that only Kimura's (1961a, 1961b; 1967) model meets the theoretical requirements in the sense proposed by Richardson (1976) and Colbourn (1978). The others: the order-effect model (Inglis, 1960, 1962a, 1962b, 1965, 1968; Inglis and Caird, 1963; Inglis and Sanderson, 1961;), the selective attention model (Treisman, 1969; Treisman and Geffen, 1968); and the multidimensional model (Bryden, 1982; Bryden, 1980; Bryden, 1967), all contribute valuable knowledge to our understanding of flaws in Kimura's (1961a, 1961b, 1967) structural-perceptual model by drawing attention to variation in DL effects that cannot be accounted for solely by the

structural-perceptual model, but none provides as parsimonious an account of hemispheric asymmetry for speech as indicated by the DL effects. Each will be reviewed in terms of its contribution to a methodology that would be responsive to a comparison of the magnitude of lateralization across subjects and conditions.

MODELS OF HEMISPHERIC ASYMMETRY

Kimura's Structural-Perceptual Model

In the original studies, Kimura (1961a; b) found that patients with damage to the left temporal region of the brain verbally reported fewer digits correctly than did patients with damage to the right temporal region. The finding was not totally unexpected, because the standard dichotic listening task involves both the ability to understand and to produce speech. The left hemisphere had long been held to be dominant in the mediation of speech production functions (Benson, 1979; Broca, 1861, 1865; Gazzaniga, 1970; Geschwind, 1972; Mountcastle, 1962; Hecaen & Albert, 1978; Reitan, 1955; Springer & Deutsch, 1981; Walsh, 1978).

A more unexpected finding, however, was that most patients, regardless of the side where the brain damage was located, reported the words they had heard with their right ear more accurately than those they had heard with their left ear. Similar results indicating a right ear advantage (REA) were obtained with normal subjects (Kimura, 1961a; b; 1967).

The auditory asymmetries, however, appeared to occur only with dichotic stimulation, and not with monaural stimulation. In fact, with monaural stimulation, a slight, albeit non-significant left ear advantage (LEA) emerged (Kimura 1961a, 1961b, 1967, 1968).

Kimura (1961a, 1967) explained her results on the basis of neuroanatomical findings derived from animal research (i.e. Rosenzweig, 1951; Tunturi, 1946), and by appealing to the now famous "competition" and "decay" hypotheses (Kimura, 1961b, 1967).

Essentially, the auditory system is not completely crossed, as is, for example, the visual system. In the auditory system, both hemispheres receive projections from each ear. Thus, stimulation arising from the right ear, for example, will travel, in part, ipsilaterally to the right hemisphere, as well as, contralaterally to the left hemisphere (Kimura, 1967; 1973; Springer & Deutsch, 1981).

Animal research has also provided evidence that in the acoustic projection system to a given cerebral hemisphere, the number of fibers from the contralateral ear is slightly greater than is the number from the ipsilateral ear (Barnes, Magoun, & Ranson, 1943; Hall, & Goldstein, 1968; Rosenzweig, 1951; Tunturi, 1946). In noting evidence that neural connections from one ear to the contralateral hemisphere are greater, and by inference "stronger" than those to the ipsilateral hemisphere, Kimura (1961a; 1967) suggested that

when two different verbal stimuli are presented simultaneously to each ear (dichotic stimulation), the difference in strength of the pathways is exaggerated so that ipsilateral and contralateral inputs "compete" in the auditory neural system. On the basis of this neural competition hypothesis, Kimura (1961a; 1967) argued that in conditions of dichotic stimulus presentation, the stronger contralateral stimulus inhibits or occludes the ipsilateral signals (Kimura, 1961a; 1967; 1973). Hence, this was termed the "competition" hypothesis.

The "stimulus decay" hypothesis was also appealed to by Kimura (e.g. 1967). The hypothesis was intended to account for the observation that subjects tend to report right-ear stimuli before left-ear stimuli with an apparent discrepancy in accuracy of report favoring stimuli presented to the right ear. Kimura (1967) argued that under dichotic presentation conditions, the stimulus to the left ear may reach the left hemisphere in one of two ways; over the suppressed ipsilateral route, or by the roundabout route over the contralateral pathways to the right hemisphere, and across the cerebral commissures to the dominant hemisphere for speech perception. Drawing from Broadbent's (1954; 1956; 1958) "bottleneck" theory, Kimura (1967) suggested that because the left ear stimulus is weaker ipsilaterally, and must traverse a more circuitous route (i.e., via the contralateral hemisphere and across the commissures), the

right ear stimulus, which travels a more direct route to the dominant hemisphere for speech perception, is more advantaged. Consequently, because of the "bottleneck," created by the competition between the ears, the left ear stimulus remains temporarily stored in the right hemisphere, where it becomes subject to temporal decay (Kimura, 1967; 1968; 1973). The stimulus decay hypothesis proposed by Kimura is quite appealing in its parsimony.

In sum, Kimura's (1961a, 1961b, 1967, 1968, 1973) perceptual asymmetry model accounts for the REA on the basis of four assumptions: (1) in the vast majority of individuals, speech comprehension and production mechanisms are localized in the left hemisphere only; (2) auditory inputs have stronger cortical representation in the contralateral hemisphere; (3) dichotic stimulation is necessary to produce lateralized effects, because information on ipsilateral ear/hemisphere pathways is suppressed at least in part, by the contralateral input; (4) information from the nondominant ear/hemisphere (in most individuals this would be the left-ear/right-hemisphere) is transferred across the cerebral commissures to the speech-dominant hemisphere for processing. There, it meets and competes with the direct contralateral right-ear/left-hemisphere inputs. Consequently, a REA for linguistic stimulation reflects the relative processing superiority of the left hemisphere as a function of information lost during the transfer of

linguistic information from the right hemisphere to the left, which is solely able to perform the speech processing task (Bradshaw, Burden, and Nettleton, 1986; Nettleton, and Bradshaw, 1983). Although the second postulate has been corroborated by a number of studies (Brugge, and Merzenich, 1973; Hall and Goldstein, 1968; Majkowski, Bochenek, Bochenek, Knapik-Fijalkowska, and Kopec, 1971; Rozenzweig, 1951), the others are equivocal.

The fourth postulate was initially corroborated by studies with commissurotomy patients, which reported substantial decreases in left-ear scores during dichotic, but not monaural stimulation (Milner, Taylor, and Sperry, 1968; Springer and Gazzaniga, 1975). This tended to suggest that on linguistic tasks, inputs from the left-ear were projected to the right hemisphere and had to be transferred across the commissures to the left-hemisphere for processing. However, all of these studies required their subjects to report verbally. Consequently, these findings are not unexpected in light of the previous arguments that the verbal report procedure likely induces a left-hemisphere bias. Later studies have reported considerably better left-ear performances when attention is focused on the left ear (Springer, Sidtis, Wilson, and Gazzaniga, 1978), and when stimulus characteristics are manipulated (Sparks and Geschwind, 1968). Also, the observation that many patients often "fuse" dissimilar dichotic inputs (Geffen, 1980; Geffen

and Quinn, 1984; Springer et al., 1978) suggests that some portion of the left-ear input may be available to the ipsilateral hemisphere in the absence of commissures (Bradshaw et al., 1986; Gordon, 1980). The third postulate, that dichotic stimulation is necessary to produce lateralized effects, has not been supported by recent investigations (Bradshaw et al., 1986; Geffen, and Quinn, 1984; Phillips and Gates, 1982). The first postulate, however, is the most problematic and the most crucial to the model, since it is regularly called upon by Kimura (1961a, 1961b, 1967, 1968, 1973) to account for the observed REA effects on linguistic DL tasks. Aside from the criticism that there is an inherent flaw in deductive reasoning that attempts to make a point by begging the question (i.e., drawing upon the assumption that speech is localized in the left hemisphere only, to account for data that has been provided as evidence in support of this assumption), there are a number of methodological issues that weaken the structure of the supportive evidence underlying Kimura's (1961a, 1961b, 1967, 1968, 1973) postulate that speech comprehension and production mechanisms are localized in one hemisphere only.

When making reference to the stimulus decay hypothesis as an account for the REA on the standard DL test, Kimura (1961a, 1967, 1968, 1973) has repeatedly assumed that the left hemisphere usually contains the neural system for not only the production of speech, but the neural system for the

perception of speech as well. The apparent basis for this assumption had been the observation of neuropathologically impaired (epileptic) patients subjected to the sodium amytal injection procedure (Wada, & Rasmussen, 1960). However the above discussion has outlined that the sodium amytal procedure only allows valid inferences regarding hemispheric asymmetries for the production of speech; it tells virtually nothing about either hemisphere's ability to comprehend speech (Gazzaniga, 1985; Kinsbourne, 1971, 1975; Searleman, 1977, 1983). In light of this, Kimura's (1961a, 1964, 1967, 1968, 1973) assumption that the dominant hemisphere for speech production is also dominant for speech perception is clearly equivocal. As well, the patient population from which inferences relative to cerebral asymmetry of function have been generalized to normals would appear to be inappropriate.

Despite these aforementioned problems, Kimura (1961a, 1961b) apparently assumed that the Wada technique and the populations observed were adequate foundations on which to base the generalized inference to normal populations that the hemisphere that is dominant for speech production is also dominant for speech perception. On this basis, Kimura (1961a, 1961b, 1967) argued that it seemed reasonable to postulate that speech sounds presented to the right ear would have easier access to the speech perception system. Using this rationale, Kimura (1961a, 1961b) explained the right ear

advantage (REA) found in most normal subjects to be a function of left-hemisphere dominance for speech perception. Evidently, there is some circularity in her arguments.

Kimura (1961a, 1961b) also proposed to test this supposition by again relying on observations of patients subjected to the Wada technique. However, these patients were dominant for speech production not in the left, but in the right hemisphere. The scores of these patients on the dichotic listening task were typically higher for the left ear (Kimura, 1961a, 1961b, 1967). Inferences from these studies led Kimura to the conclusion that these results supported the hypothesis that the REA in normal subjects was due to better connections between the ear contralateral to the hemisphere dominant for speech production, and by inference, speech perception (Kimura, 1967). However, these findings are similarly subject to the same criticism that stimulus production mechanisms are simply reversed in this sample, and that the verbal response required of her subjects may have induced disproportionate ear asymmetries.

The above discussion has outlined that the neural substrate necessary for language production is localized primarily in one of the two cerebral hemispheres (for the large majority of right-handed individuals this would be the left hemisphere). This notion is now generally accepted. However, the issue of cerebral lateralization of language processors (i.e., language perception) has not yet been

resolved in any conclusive manner (Gazzaniga, 1974, 1977; Mohr, 1982). The contentious issue is whether linguistic cerebral processors are lateralized to the same extent as expressive mechanisms, or whether there is bilateral processing of some aspects of such stimuli (Springer & Gazzaniga, 1975).

As we have seen, dichotic listening and the observed ear advantages have been instrumental in addressing this problem in normal, as well as patient populations. A number of investigators have provided valuable insights into those factors that may contribute error variance in the DL paradigm. These authors have presented their arguments in the form of alternative models for observed laterality effects. They include:

- (1)- Inglis' (1960, 1962a, 1962b) Order-effect model;
- (2)- Treisman's (1960, 1964a; 1964b, 1969) Selective attention model
- (3)- Bryden's (1967, 1980) Multidimensional model.

While each model has contributed substantially to a deeper understanding of functional asymmetries, all have problems associated with them (Mohr, 1982). However, the structural-perceptual asymmetry model of Kimura (1967) has generally been argued to provide the most cogent explanation of REA in DL (Bryden, 1967; Mohr, 1982; Studdert-Kennedy, 1975). The alternative models, however, deserve serious consideration because they account well for a number of

factors that may contribute considerably to the REA variance observed on the DL task.

Order-Effect and Memory Factors

A number of authors have reported that with the free recall of dichotic verbal material, subjects tend to report all the stimuli presented to the right ear first, followed by some of the stimuli presented to the left (Broadbent, 1954, 1956; Bryden, 1982; Inglis, 1960, 1962a, 1962b, 1965, 1968; Inglis and Caird, 1963; Inglis and Sanderson, 1961). According to this model, the REA is accounted for by the fact that the stimuli presented to the right ear are the first to be processed successively by the speech perception system in the left hemisphere, while the stimuli presented to the left ear are kept in storage in the right hemisphere until the perceptual system is free to process the stimuli from the left ear. While awaiting processing, the stimuli from the left ear become subject to temporal decay in the right hemisphere (Broadbent, 1957a, 1957b; 1958; Bryden, 1962, 1967; Inglis, 1968). According to Broadbent's (1957a, 1957b, 1958; Inglis, 1965) model of perceptual asymmetry, the REA on the DL task represents the cerebral asymmetry of two systems; a perceptual system, presumably situated in the left hemisphere, and a storage system, presumably situated in the right hemisphere (Broadbent, 1957a, 1957b, 1958; Inglis, 1965).

Using this model, a number of authors have demonstrated

a progressive age-related decrement in the free recall of verbal material presented to the left ear, without any similar decrement for material presented to the right ear. This was seen as confirming the hypothesis that memory processes play an important role in DL effects in both normal aging (Broadbent and Gregory, 1965; Inglis, 1962a, 1962b; Inglis and Tansey, 1967a, 1967b; Caird, 1965; Craik, 1965) and in patients with memory disorders (Caird and Inglis, 1961; Inglis, 1960; Inglis and Sanderson, 1961). Bryden (1967, 1962) has suggested a slightly modified explanation: he argued that short-term memory processes may simply be more efficient in the left hemisphere than in the right (Bryden, 1967, p.596). Still another explanation may be found in a recent review of dichotic listening literature by Mohr and Costa (1985). They reported that laterality scores tend to increase (i.e., ear asymmetry increases) for the same subject as task difficulty increases. Thus, it is conceivable that a verbal report DL paradigm involving serial stimulus presentations could produce greater REAs than single pair presentations of the same material.

As an alternative account for order-of-report effects, Oxbury, Oxbury, and Gardiner (1967) have suggested that the REA reflects an attentional bias induced by requiring subjects to respond verbally. Their contention is that left cerebral dominance for speech production may create an attentional bias for the stimulus material presented to the

right ear to be recalled first in sequence in a free-recall procedure. In support of this view, Penney (1976) has provided evidence from a dichotic memory task, which indicates an actual division of attention between two competing inputs.

Mohr (1982) has suggested that the Broadbent effect may merely represent the storage format of items. Inglis (1965) had suggested that to provide a satisfactory account for why the order-effect occurs in the first place, it is necessary to specify the ear order of recall from the subject in order to discriminate errors in reproduction that are due to order-effect from those that are due to laterality, and corresponding to Broadbent's hypothesis, due to defects of short-term auditory storage. Using this suggestion, Mohr (1982) demonstrated that memory factors indeed are involved in DL performance. However Mohr (1982) did not control for the mode of response; all of his subjects used a verbal mode of response. Thus, although Mohr's (1982) findings provided evidence that a memory component does contribute to the DL effect, they did not speak to the issue addressed by Oxbury, Oxbury, and Gardiner (1967) or Kinsbourne (1972); that is, that left cerebral dominance for speech production may create an attentional bias for the stimulus material presented to the right ear to be recalled first in sequence in a free-recall procedure.

A more damaging criticism to the order-effect model is that it fails to account for why some authors have found a REA for single pair presentations, which should not elicit a memory component on DL performance (Studdert-Kennedy and Shankweiler, 1970). Neither does this order-effect, which is based on Broadbent's theory of lateralized memory storage, account for reports of a REA on DL with monaural presentations (Frankfurter and Honeck, 1973; Turvey, Pisoni, and Croog, 1972). As well, a number of independent studies have demonstrated that the primary/secondary channel paradigm fails to account for the finding that the right ear is more efficient than the left for both immediate and delayed orders of report when order of report is experimentally counterbalanced between each ear (Borkowski, Spreen and Stutz, 1965; Bryden, 1967; Satz, Achenbach, Pattishall, and Fennell, 1965). As Mohr (1982) has indicated, the literature cannot be interpreted as supporting order-effect accounts for the REA on DL tasks. An account for the effect, which has not been given careful consideration to date, is Kinsbourne's (1972, 1973, 1975) notion that an expectancy set or mental priming, which would create a right ear bias in attention may lie at the source of much of the ear asymmetry variance not accounted for by the structural-perceptual model. Kinsbourne (1972) provided evidence indicating that activity occurring within a hemisphere will bias a subject's attention to one side of space or the other. Conceivably, instructing a

subject that the mode of response will be verbal on a DL task can bias a subject's attention to the right side of space since the subject must prepare the left hemisphere in order to respond. Such left-hemisphere priming could result in an attentional bias to the right side of space, producing an REA. Spellacy and Blumstein (1970a, 1970b) provided some experimental support for Kinsbourne's theory. However, a number of other studies have been unable to replicate this finding (Allard, and Bryden, 1979; Gardner and Branski, 1976; Boles, 1979). Nevertheless, Kinsbourne's (1973, 1975) hemispheric priming theory has generated considerable interest in experiments designed to see whether different types of words can prime the hemispheres differentially. Bryden and Ley (1983) have reported evidence from tachistoscopic and DL studies indicating that high imagery words and emotional words could elicit right-hemisphere but not left-hemisphere priming effects. Neutral words produced no such effects. These findings provide additional support for the argument that the right hemisphere plays an important role in imagery and affect, and in the mediation of high imagery words and emotional words (Searleman, 1977, 1983; Coltheart, 1983). Bryden and Ley (1983), have argued that their findings indicate that Kinsbourne (1973, 1975) cannot be correct in the general assertion that verbal thought activates the left hemisphere only. Rather, it would appear that under certain conditions, verbal material may also

activate the right hemisphere (Bryden and Ley, 1983). They also suggested that such an interpretation need not imply that the words have affective or imagery component, but merely that prolonged study of highly imageable or emotional words may lead to the activation of some general concept of imagery or affect. Although the argument is plausible, their experimental data did not support such a conclusion.

An alternative account for their findings may be that although high imagery words and emotional words do not in and of themselves have imagery or affective components, they are so labeled because they do tend to elicit multisensory and/or emotional experiences, both of which may involve the right hemisphere to a greater degree than the left hemisphere. Consequently, highly imageable and emotional words would tend to produce right-hemisphere but not left-hemisphere priming effects. The converse may also be true for left-hemisphere priming effects with words that are neutral or abstract.

The notion that expectancy may underlie some of the variance in ear asymmetry on the DL task, and thereby induce an asymmetric priming effect is worthy of further investigation. If right-hemisphere priming effects can be induced by words that can elicit multisensory or emotional experiences (i.e., highly imageable and emotional words), it is equally conceivable that left-hemisphere priming effects may be similarly induced by the use of abstract or low imageability words and/or neutral words (i.e., words that do

not arouse emotional and/or multisensory experiences).

Using this same line of reasoning, the question thus arises that by requiring a subject to respond verbally in a DL paradigm may also induce left-hemisphere priming effects that compound with stimulus characteristic (e.g., word-type) to elicit significant REAs. The alternative may also be true; that is, right-hemisphere priming effects may be similarly induced by requiring subjects to respond manually (i.e., with their left hand) to presentations of highly imageable and emotional words. Whether such priming effects result in an attention bias (Kinsbourne, 1973, 1975) or induce the degradation of ipsilateral inputs may remain undetermined until more detailed investigations have outlined the different factors that contribute to priming effects. To date, no published reports have examined all of these factors in conjunction. A number of studies, however, have investigated them separately.

In an interference dichotic task, McFarland, McFarland, Bain, and Ashton (1978) reported that the right hemisphere was more efficient at processing concrete than abstract words. When speech was used as interference during a running memory span auditory recognition task, a REA was obtained with abstract but not with concrete words. Using a more conventional verbal report paradigm, Kelly and Orton (1979) reported similar findings with stimuli that had mixed imageability values. They found that both hemispheres were

efficient at processing highly imageable words, but the left hemisphere performed better than the right hemisphere when the stimuli were low imageability words. However, not all investigators have been able to produce such effects.

In a word detection paradigm involving concrete and abstract words of high and low frequency that were paired with monosyllabic neologisms, Prior, Cummings, and Hendy (1984) were unable to find evidence supporting differential hemispheric processing of concrete and abstract words. However, their investigation had a number of methodological flaws. Their task required subjects to respond only to the occurrence of a real word in either ear by pressing with the index fingers of both hands, two keys, either of which recorded the subject's response time (RT). An examiner recorded the subject's accuracy. The authors report that because of the extreme variability in their RT data, they deemed it unsatisfactory to use as a dependent measure, and supplanted this dependent measure with accuracy data. It is uncertain whether their subjects were responding more efficiently with one hand or the other, responding with one hand more than the other, or whether they were devoting more attention to one ear or the other. The extreme variance in RT data, however, highlights two important points: (1) it corroborates the contention put forth by Graves and Morley (1986) that the basic issue of varying overall performance is not overcome by the use of RT data as the dependent measure;

and (2) the substitution of mathematically transformed accuracy data for RT data would appear equally inappropriate for comparing the magnitude of ear asymmetry in DL paradigms. Different transformations produce discrepant asymmetries as a function of overall accuracy (see Graves and Morley, 1986). Furthermore, Prior and colleagues (1984) did not control for variation which may have been due to such factors as attention (Treisman, 1969) and hemispheric priming (Bryden 1982; Bryden and Ley, 1983). The inclusion of both sexes in this study also seems unwarranted in light of the small sample ($N = 32$), the complexity of the design, and the number of analyses conducted. In combination, these factors may have induced spurious results (Hummel and Sligo, 1971). On a more conceptual level, the experimental hypothesis advanced by Prior and colleagues (1984) held that the degree of ear asymmetry (i.e., REA) might vary as a function of subject and stimulus attributes. This hypothesis clearly calls for the demonstration that the subjects had an REA, before it can be demonstrated that stimulus or subject factors can influence the degree of the REA effect. They reported that only one third of their subjects had an REA. The fundamental question of demonstrating variation in the degree of hemispheric asymmetry is thus problematic, since the majority of their subjects did not show a basic effect with regard to the direction of ear asymmetry.

Different stimuli may produce differential priming effects resulting in varying REA scores in DL paradigms. This may account for reports of varying degrees of ear asymmetry. Liberman, Cooper, Shankweiler, & Studdert-Kennedy (1967), have reported differences in REA with manipulations of stimulus characteristics. They found that stop consonants typically produce the most robust REA, whereas vowels produce only a small REA. Spellacy and Blumstein (1970a, 1970b) found a right ear effect for vowels when they appeared in the context of other word pairings, but a left ear effect for the same stimuli when paired in the context of nonverbal material. Other factors have also been demonstrated to contribute to the ear asymmetry variance. Weiss and House (1973) and Godfrey, (1974) have reported significant REAs can be produced with vowels, if the task is made difficult. Task difficulty would thus appear to also contribute to asymmetry variance in DL paradigms (Mohr, and Costa, 1985). Using a fused-words procedure, Repp (1978) found that manipulations of voice onset time resulted in significant and robust REAs. Questions regarding the magnitude of REAs in relation to different classes of phonemes have yet to be answered (Bryden, 1982).

On the basis of this evidence, the question arises that the priming effects of stimulus materials may possibly interact with the priming effects of the mode of response, to

produce compounded ear asymmetry measures in DL paradigms. Such a state of affairs is in fact suggested by Haggard & Parkinson (1971). They have argued that task factors may be important determinants of ear advantages. They proposed that the term "task" should be interpreted as a function of the use to which "certain stimulus information has to be put" (p. 176), rather than solely as the questions asked of a subject. However, they were unable to elicit significant LEA effects in their experiment. In light of previous reports that stimulus factors such as imageability (Bryden and Ley, 1983; Day, 1977, 1979, Hines, 1975) and emotionality (Bryden and Ley, 1983; Graves et al., 1981) can elicit right-hemisphere effects, that robust REAs are typically found with initial stop-consonants (Shankweiler and Studdert-Kennedy, 1967; Studdert-Kennedy and Shankweiler, 1970), and that task complexity tends to elicit REAs (Mohr, and Costa, 1985), then Haggard and Parkinson's (1971) failure to demonstrate a significant LEA may have been a function of the stimuli and the task they employed. They used consonant-vowel (CV) combinations in one experiment, and complex sentences in the other. Both should conceivably induce left-hemisphere bias rather than elicit evidence of right-hemisphere linguistic capabilities. Despite these procedural difficulties, Haggard & Parkinson concluded, with considerable foresight, that response procedure alone should not be expected to control ear advantages without stimulus information relevant to the

response required.

The debate over the relative contributions of attentional bias (Kinsbourne, 1973, 1975) versus priming effects (Bryden and Ley, 1983) in eliciting hemispheric asymmetry variance in DL paradigms may be less relevant than an understanding that such factors possibly reflect functional flexibility in the face of changing environmental contexts and demands. Such flexibility in linguistic processing may account for many of the controversial findings on observed DL effects. Functional flexibility is perhaps best exemplified in paradigms that have manipulated attentional factors (Moray, 1970; Treisman, 1960, 1969).

Attention Factors

Treisman (1969) suggested that a structural-perceptual account of laterality effects on the DL task is incomplete without consideration for the selective aspect of perception and response (Treisman, 1969). Treisman (1969) argued that two attention factors might account for laterality effects on the DL task; a focused attention variable, and a divided attention variable, which might reflect the brain's ability to use two analyzers simultaneously and the subject's ability to test for two target's simultaneously (Treisman, 1969).

In an adaptation of Cherry's (1953) "shadowing" technique, Treisman and Geffen (1968) demonstrated a REA with shorter, memory independent DL task sets. Their findings demonstrated that quantitative differences in the

distribution of attention to the left and right ear inputs contribute significantly to the variance of observed REA on the DL task. However, Treisman and Geffen (1968), assumed that the reference point for linguistic processing and this distribution in attention was the left hemisphere. In light of the hypothesis that left-hemisphere cerebral dominance for speech production may create an attentional bias for material presented to the right ear (Inglis, 1965; Haggard and Parkinson, 1971; Kinsbourne, 1972; Liberman, Cooper et al., 1967; Oxbury et al., 1967; Penney, 1976; Spellacy and Blumstein, 1970a, 1970b; Springer, 1973), and the fact that the shadowing task employed by Treisman and Geffen (1968) required a verbal response from the subject, it is equally plausible the right ear attention bias they reported and attributed to left-hemisphere dominance for speech perception could have been induced simply by left-hemisphere dominance for speech production. Thus, the task demands (i.e., requiring a verbal report from their subjects) could have induced the REA observed on their shadowing task. The difficulty of this task may also have contributed to the REA effect (Mohr and Costa, 1985).

It would appear that structural-perceptual (i.e., physiological) processes, memory and storage capacities, task complexity, as well as, hemispheric priming and attentional variables all can contribute to the variance observed right-left differences on the DL task. However, the various

experimental designs which produced this important information all shared two things in common; they generally required a verbal response from their subjects, and all produced a clear REA in their subjects. Thus, each experimental design failed to control adequately for the possible confounding of stimulus type interacting with the mode of response. Presumably, the authors started with the same basic assumption; that speech perception is localized in the left hemisphere. Nevertheless, the findings reported from the aforementioned studies did show that multifactorial sources of variance probably contribute to the REA on the verbal dichotic listening task. Bryden (1980, 1982) has described these sources variance more elegantly than most of his contemporaries.

Multifactorial Variance Sources

Bryden (1967, 1980, 1982) has maintained that hemispheric asymmetry provides only a partial explanation for the observed REA on the DL task. Numerous other factors including attention, memory, order effects, subject strategies, stimulus material, task complexity, and response requirements all contribute to the variance observed on the DL task. However, no one factor, except for perhaps true structural-perceptual asymmetry, probably accounts for more of the variance distribution than the others (Bryden, 1967, 1982).

Still, Kimura's (1961a, 1961b, 1967) structural-perceptual asymmetry model fails to account for the evidence which suggests that perceptual asymmetry may not be a totally fixed entity; that the left hemisphere's superior efficiency at linguistic processing may simply be a bi-product of left-hemisphere dominance for speech production, which does not necessarily imply that the right hemisphere is incapable of linguistic processing, but merely that it probably is less efficient at this task. It would seem, therefore, important to investigate the hypothesis that the bi-hemispheric transfer of linguistic information is more or less occluded in a DL task when the mode of response and/or stimulus characteristics favor(s) one hemisphere over the other. An alternative account might be that the apparent occlusion of this bi-hemispheric transfer of linguistic information is an artifact of the confounding of the stimulus material with the mode of response measure used by the experimenter (i.e., the task demands). As well, the dependent variable used by the experimenter, such as number of items correctly reported by the subject or mathematical transformations of these data, which are nominal scale variables, might also contribute to a clouding of any observable hemispheric asymmetry variance accountable for by right-hemisphere speech processing capabilities, and/or the bi-hemispheric transfer of linguistic information.

The question that even additional other sources of variance may contribute to observed lateral asymmetry effects on the DL task has been addressed by Mohr (1982).

Other Sources of Variance

The question that individual differences in "psychological differentiation" or "cognitive style" might also find expression as individual differences in perceptual asymmetry, attentional asymmetry, and other factors which might contribute to observed asymmetry on the DL task, has interested a number of researchers (Dawson, 1972; Pizzamiglio, 1974; Pizzamiglio and Cecchini, 1971; Witkin, Goodenough, and Oltman 1979). Mohr (1982) has reviewed a number of such investigations.

Witkin, et al., (1979), had contended that greater or lesser degrees of the field dependence/independence, as indicators of individual differences in "psychological differentiation" or "cognitive style", might find expression in psychological as well as physiological measures. Support for this theory was found in earlier work by Pizzamiglio and Cecchini (1971), Dawson (1972), and Pizzamiglio (1974). They had consistently found a greater REA on the DL task with verbal stimuli in field independent individuals than in field dependent individuals. Based on these and additional findings by Dawson (1977), Witkin and colleagues (1979) concluded that field independent subjects should show greater left-hemisphere linguistic processing than field dependent

subjects. This notion of "psychological differentiation" or "cognitive style", shared many similarities to Palmer's (1964) earlier idea that lateralization of functions emerges by a process of differentiation. However, Mohr (1982) was unable to demonstrate significant effects for field dependence/independence on DL scores.

Using similar reasoning as the above authors, Charman (1979) hypothesized that extraverts and introverts (Eysenck, 1970; 1963) might be differentiated with respect to hemispheric asymmetries. Charman (1979) based his hypothesis on previous investigations which had demonstrated that for the majority of right handed males, the left hemisphere appeared more efficient at processing information in a verbal-analytic fashion, whereas the right hemisphere appeared more efficient at processing information in a visuo-spatial fashion (Davis and Schmit, 1973; Dimond, 1972). Furthermore, in light of Eysenck's (1963, 1970) evidence that extraverts preferred and adapted to greater degrees of stimulation than introverts, Charman (1979) hypothesized that in a tachistoscopic test of hemispheric information processing, extraverts should recall information about letters in various patterns more efficiently in the left visual field (i.e., right hemisphere) than in the right visual field (i.e., left hemisphere), whereas introverts should demonstrate a converse pattern of performance. Charman (1979) provided evidence in support of this

hypothesis; that is, along the extraversion continuum (Eysenck, 1970; 1963), extraverts showed more efficient letter recognition for left visual half-field (i.e., right hemisphere) tachistoscopic presentations whereas introverts showed a converse pattern.

Conceivably, if introversion did reflect a certain "cognitive style" along a continuum of "psychological differentiation", then Charman's (1979) findings should replicate in a DL paradigm. Thus, individuals who endorsed more items suggestive of introversion should have higher REA scores on the DL task than individuals who endorsed more items suggestive of extraversion. To this writer's knowledge, no investigator has yet attempted to address this issue in a DL paradigm.

The rationale for undertaking such an investigation stems from the hypothesis that introversion may reflect a more field independent cognitive style than extraversion, which would tend to reflect a more field dependent cognitive style. This hypothesis rests on the basic assumption that the scores provided by personality inventories such as the Eysenck (1970; 1963) Personality Questionnaire are valid measures with which to hypothesize continuums of personality dimensions such as extraversion, and that a respondent's endorsement of the items comprising these instruments does indeed reflect such personality dimensions. The basic question then becomes one of selecting an appropriate

questionnaire.

The Eysenck Personality Inventory (EPI) is the best known self-report inventory specifically measuring extraversion (E) and neuroticism (N), the two major personality dimensions to have emerged consistently from analyses of questionnaires and personality ratings such as the Minnesota Multiphasic Personality Inventory (MMPI) (Tellegen, 1978). Considerable research has gone into the development of this scale; over 30,000 subjects were involved in the repeated factor analyses and research on the various sets items from which the E and N dimensions were derived. The test presents good test-retest correlations of .81 and .85 for the N and E scales, respectively (Eysenck, 1970). The test-retest reliabilities range between .80 and .97 (Cline, 1972). It has more items that directly address the N and E measures (24 items for each scale) than comparable questionnaires purporting to address the same personality dimensions. For research purposes the EPI offers Eysenck's (1970) well developed theoretical framework, and the convenient parsimony of two personality dimensions that may be measured with orthogonal scales. For research involving Eysenck's (1970) personality theory, the validity of this instrument appears unquestioned (Lanyon, 1972). The N and E personality factors have been argued by Eysenck and Eysenck (1969) to account for most of the variance in the personality domain. Thus it would seem the logical candidate in an

investigation designed to determine the validity of Charman's (1979) hypothesis that hemispheric asymmetries for speech can correlate with personality dimensions such as extraversion. Using this line of reasoning, it seems plausible that if gross personality dimensions such as extraversion and neuroticism could bear some relationship on tasks designed to determine hemispheric asymmetry, then other instruments such as Cattell's (1970, 1972) 16 PF questionnaire, should for similar reasons, be able to provide indices of personality correlates of hemispheric asymmetry for speech.

SUMMARY AND RESEARCH PURPOSE

Summary

The foregoing review has attempted to acquaint the reader with the most popular investigative methods applied in hemispheric asymmetry research. Regardless of the method used, the evidence is fairly compelling that in most people, language is represented primarily in the left hemisphere, and that lateralization seems to be more pronounced with respect to the expressive components of language than with respect to its perception and/or comprehension. With regard to the latter, hemispheric asymmetry would appear to largely a matter of degree.

The goal of the review was to outline the advantages and disadvantages that apply to each method. Continued developments will most certainly produce new methods allowing more direct investigations of lateralized functions in the future. Until such time, however, researchers will need to continue refining available methodologies such as tachistoscopic and dichotic paradigms. There are conceptual, as well as, general and specific methodological problems related to both methods. The data obtained from investigations with clinical patients should continue to be of critical significance in outlining the research questions, although it has perhaps been accorded more relevance with regard to neurologically normal individuals than its value

merits. If the researcher's goal is to arrive at a better understanding of lateralized functions in normal subjects, then normal subjects should be the population of choice (Heilman, 1983).

Because no method is completely free of methodological difficulties, it may behoove investigators to scrutinize each method, and if his/her resources allow it, select one that satisfies the requirements of a strong test of the operational definition of their model of cerebral asymmetry, and persist with the method. This should provide the researcher with a better opportunity to master the relevant methodological difficulties inherent in the method. More systematic attempts to study the nature of methodological limitations of the reviewed methods are needed if solutions are to be found.

The confusion that characterizes current laterality literature also heralds the need for more reflection in the design of experiments; few of the studies reviewed provided a strong test of their experimental hypotheses. Too few experiments have considered the influence of experimental tasks on measures of human performance. This issue clearly needs to be re-evaluated in cognitive terms. Accordingly, cognitive and performance variables will need more stringent control. The tasks presented to subjects will also need more strict operational definitions of the processes they purport to measure. Methodological developments should focus on

parametric manipulations of the target variable(s) with careful control over potential sources of variance such as stimulus and response factors. There is also a need to develop valid indices of hemispheric asymmetry and to apply statistical procedures which will allow the assessment of within-subject variability in lateralized functions.

Finally, more experiments with dextrals of the same sex need to be compared with attempted replications with sinistrals of the same sex, rather than using mixed-samples with too few subjects.

Research Purpose

In light of the foregoing review, it is apparent that high left-hemisphere speech competence can be assumed in most right-handed males. Consequently, varying degrees of differential hemispheric ability can be taken to represent varying degrees of right-hemisphere linguistic competence. It is also conceivable that in a strictly controlled DL paradigm, ear asymmetry variance could be manipulated as a function of: (1) the mode of response required of the subject, (2) the type of stimulus presented to the subject, and (3) the task demands (i.e., mode of response required of the subject interacting with the type of stimulus material presented to the subject). Thus, in a DL paradigm involving linguistic material, verbal vs manual modes of response may produce discrepant effects.

If an expectancy set could conceivably be created by simply telling a subject that a verbal response is expected, it is equally conceivable that right-hemisphere priming effects could similarly be elicited by instructing a subject to respond manually to a verbal stimulus; for example, a button press with the left hand only. If right-hemisphere priming could be so induced, then it might produce a relative decrement in REA for the same stimulus material. Different types of stimuli such as abstract words, highly imageable words, and emotional words might also contribute to ear asymmetry variance by producing differential priming effects for each hemisphere. Based on previous findings, it is conceivable that abstract words could elicit greater REAs than either concrete (i.e., highly imageable) or emotional words, which have been shown to elicit LEAs.

Accordingly, if all stimuli were controlled for length and frequency of occurrence (Kucera & Francis, 1967), and that only the imageability and emotionality dimensions of the stimulus words (Paivio, Yuille, and Madigan, 1968) were manipulated this might allow inferences with regard to the relative influence of these factors on hemispheric asymmetry for speech in a DL paradigm. The notion seems plausible in light of reports that clinical (e.g., Gazzaniga, 1970; Ellis, & Shepherd, 1974) as well as normal (e.g., Day, 1977, 1979) investigations have observed the right hemisphere to be quite

proficient at recognizing noun-object (i.e., highly imageable) words.

As well, a number of authors have demonstrated and argued that right-hemisphere speech may be facilitated by the use of emotional words (Day, 1977, 1979; Graves et al., 1981; Hines, 1976; McFarland et al., 1978; Moscovitch, 1983). Moscovitch (1983) has argued that all emotions are mediated primarily by the right hemisphere, and that stimuli eliciting strong emotional reactions are more likely to be those that demand an immediate response. However, other authors have argued that negative emotions are mediated primarily by the right hemisphere and positive ones by the left (see Tucker, 1981 for a review). Kolb and Taylor (1981) have proposed a third alternative, suggesting that the mode in which emotion is expressed may determine the hemisphere to which it is lateralized. Thus, verbal expression would lead to left-hemisphere lateralization and nonverbal expression would lead to right-hemisphere lateralization. Their postulate would appear to converge with Bryden and Ley's (1983) priming hypothesis.

Moscovitch (1983) proposed that regardless of stimulus type, differences in performance suggest differential hemispheric performance at higher levels of processing. In many instances, however, as in processing the semantic properties of language, hemispheric differences are likely to be small because each hemisphere contributes in its own way

to the task at hand (Moscovitch, 1983). He emphasized the importance of factoring out those variables that determine the relative contribution each hemisphere makes on a given task. Based on an extensive review of the literature, Moscovitch (1981) concluded that although the right hemisphere can process verbal information semantically, normal people tend to rely primarily on the left hemisphere to mediate this modality. As an explanation he proposed that functional localization may occur because the left hemisphere inhibits the right hemisphere's linguistic functions, or it may be more efficient and faster at linguistic tasks, and/or because subjects choose strategies that are more compatible with left rather than right-hemisphere processes. Although Moscovitch (1983) does not provide any hypotheses as to what factors might induce such effects, Bryden and Ley's (1983) priming hypothesis, as well as Kolb and Taylor's (1981) mode of expression bias would seem to converge as one explanation, especially with regard to Moscovitch's (1983) notion of flexibility in subject strategies.

In the IID experiment that follows, I attempted to systematically control the conditions which might elicit the right hemisphere's linguistic abilities, particularly its semantic ones. It was believed that under some circumstances, the right hemisphere's semantic abilities might emerge and influence normal performance. Such circumstances might then account for occasional observations

of right-hemisphere processing of, for example, concrete words (e.g., Day, 1977, 1979).

Moscovitch (1983) has speculated that by overloading the left hemisphere one might then facilitate the right hemisphere's linguistic abilities to become apparent. A second possibility he has suggested is that the presentation of stimuli or of tasks that naturally engage the superior processing mechanisms of the right hemisphere might also elicit this effect. Citing evidence from a number of studies, Moscovitch (1983) argued that although each hemisphere encodes identical information in a manner commensurate with its abilities, on verbal tasks, special techniques may be required to free the right hemisphere from the dominance of the left in order to reveal its contribution to normal performance. Because previous reports have provided evidence of stimulus and task factors contributing to ear asymmetry variance, the question would appear to be one of determining which factors might induce hemispheric asymmetry variance.

In contrast to these reports, Kimura (1968) has provided evidence for and argued that the critical distinguishing characteristics of speech sounds are not related to meaningfulness, familiarity, or conceptual content. Kimura's position with regard to the right-hemisphere's ability at distinguishing stimulus characteristics of imageability and emotionality is uncertain.

On the basis of this review, it would seem plausible that the type of stimulus used, interacting with the mode of response may contribute significantly to ear asymmetry variance. Based on previous reports, one would expect that a verbal mode of response should elicit greater REAs for abstract words than for concrete or emotional words, whereas a nonverbal mode of response would be expected to elicit a similar, but less dramatic pattern, since concrete and emotional words have been shown to elicit LEAs.

In accordance with the aforementioned issues, an experiment was designed in an attempt to explore the utility of a novel method of quantifying the dichotic listening ear advantage, in delineating the influence of stimulus characteristics and mode of response on the method's measurement of hemispheric asymmetry for linguistic function. An additional aim of this investigation was to control for task difficulty, attentional bias factors, and order of report because all of these may be contributing potentially significant variation, which can influence the degree if not the direction of the observed REA in the DL paradigm.

The interaural intensity difference (IID) procedure (Graves and Marcopulos, 1985; Graves and Morley, 1986) was chosen because it is purported to provide a methodology that is appropriate for comparing the magnitude of lateralization scores across subjects and conditions. Because the model of hemispheric asymmetry adopted for this investigation proposes

that the degree and direction of ear advantage may be shown to be a function of the type of stimulus and the required response when attentional bias and task difficulty are under experimental control, the IID procedure seemed well suited for the aims of this investigation.

The method is a psychophysical threshold procedure that works much like audiometric threshold tests which use words and/or pure tones. The advantage of such procedures is that they provide unequivocal ordinal scale data that are readily amenable to statistical analyses while corresponding directly to stable indices of performance. Consequently, the method allows the investigation of not only direction, but also degree of ear asymmetry for different subjects and/or stimuli in DL paradigms.

In contrast to conventional DL methods, which attempt to maintain constant stimulus conditions and allow performance (i.e., accuracy or RT) to vary and become the dependent measure, the IID procedure (Graves and Marcopulos, 1985; Graves and Morley, 1986) does the converse in that it attempts to maintain performance constant by varying the stimulus conditions. The degree of variation in the stimulus conditions then becomes the dependent measure. The principle underlying the application of this method in DL paradigms stems from earlier work by Berlin, Lowe-Bell, Cullen, and Stafford (1972). They had demonstrated that it is possible to eliminate the REA for the report of CV syllables by

attenuating the intensity of the right-ear stimulus by approximately 15 dB.

In a creative interpretation of this finding, Graves and Marcopulos (1985) reasoned that ear advantage could be quantified in terms of the differential attenuation (i.e., degradation of stimulus intensity) required to produce approximately equal accuracy for both ears. Thus, in a subject with a REA, the right-ear stimulus would require more stimulus degradation in order to produce performance approximately equal to that of the left-ear. Manipulations of the IID until performance reaches a constant predetermined level of accuracy would thus provide a general way of quantifying the ear advantage across ears, subjects, and conditions (Graves, and Morley, 1986).

The IID is analogous to a signal to noise ratio. In a DL paradigm the signal corresponds to the target presented to the attended ear while the noise corresponds to competing stimulus presented to the unattended ear. By varying the intensity of the target word as a function of the subject's accuracy while maintaining a constant intensity of competing stimulus presentation, it is possible to derive a measure of ear advantage. Better ability corresponds to a lower signal to noise ratio (IID). The left ear IID minus the right ear IID may then be defined as the measure of ear advantage (Graves and Morley, 1986). When the noise is presented at a constant level in both ears, ear advantage may alternatively

be defined as right ear attenuation minus left ear attenuation. In either case, a positive value would correspond to a REA while a negative value would correspond to a LEA.

Thus, the IID procedure was adopted for this study because it provides a methodology that allows the derivation of an index of functional cerebral organization in terms of the following fundamental assumption: the magnitude of directional ear advantage in a DL paradigm corresponds to the degree of functional cerebral organization occurring for a given task.

In sum, because a high degree of left-hemisphere auditory verbal competence can be assumed, varying asymmetry on a measure of differential hemispheric ability can be taken to represent varying degrees of right-hemisphere linguistic competence. The overall purpose of the experiment was to determine whether task demands (i.e., stimulus type interacting with mode of response) influence differential hemispheric asymmetry of auditory verbal discrimination, and hence, right-hemisphere ability.

The experimental hypotheses were: (1) that much like other asymmetry measures, the IID procedure could provide a gross index of hemispheric asymmetry, and as such, the overall REA (collapsed across modes of response and stimulus categories), would be positive and thus reveal a generally greater left-hemisphere efficiency at mediating linguistic

material; (2) that the verbal mode of response would elicit greater overall REAs than the manual mode of response (i.e., a main effect for mode of response collapsed across stimulus categories); (3) that a main effect for stimulus category would be apparent, with abstract words eliciting greater REAs than concrete or emotional words (collapsed across modes of response); (4) that any substantive REA variance (suggesting right-hemisphere competence) in the processing of auditory verbal stimuli (i.e., words) would be found mainly as a function of a stimulus category by mode of response interaction; (5) that a trend would emerge, wherein abstract words elicit greater REAs than do concrete or emotional words (i.e., a quadratic component), as has been reported for visually presented words; and (6) that introversion would correlate positively with the overall REA on either the standard dichotic listening test or the IID procedure.

METHOD

General

Each subject began the experiment by first reading a statement of intent (Appendix A) and signing a consent form (Appendix B). Thereafter, the subject was asked to rate the stimulus words in terms of imageability (Appendix C) and emotionality (Appendix D), and to complete form A of the Eysenck Personality Inventory (Eysenck, 1963, 1970) (Appendix E) while sitting quietly by himself in the anechoic chamber. This allowed each subject approximately ten minutes to adjust to the ambient atmosphere of the anechoic chamber. At all times when the subject was alone in the anechoic chamber, a system of microphones and speakers allowed him to be in constant contact with the examiner.

An audiometric hearing test was then administered with a calibrated Grason-Stadler 1707 portable audiometer (Grason-Stadler, 1977). Formal testing for normal hearing was conducted at the following frequencies: 500, 1000, 2000, and 4000 Hz. The standard audiometric testing consisted of a 40 dB practice trial at each frequency, followed by ascending monaural stimulation beginning at -10 dB and increasing by 5 dB until the subject indicated having heard the tone by raising his hand. Threshold levels for each of the frequencies tested were established in the same fashion and replicated by decrements of 10 dB and increments of 5 dB.

Participants with a hearing loss of 10 dB or greater at any frequency for either ear were considered to have deficient hearing acuity for the purposes of this investigation and were excluded from the study. As well, any subject with a 10 dB or greater difference between the right ear and left ear for any frequency was also excluded from the study because a number of authors have reported that interaural intensity differences of 8-10 dB yield significant differences on DL performance (Berlin, Cullen, Hughes, Berlin, Lowe-Bell, and Thompson, 1975; Chocolle, 1962; Roeser, Johns, and Price, 1962). Of the 73 paid participants, a total of 13 were excluded because of hearing deficiencies.

Subjects who passed the audiometric hearing test were then administered a standard dichotic listening test (Hayden, and Spellacy, 1969), which consisted of 66 pairs of words presented in sets of three to each ear (Appendix F). The stimuli were recorded on a Nakamichi (BX-100) two head cassette deck and presented on a TEAC A-108 Sync stereo cassette deck and delivered via a set of Sennheisser (HD 222) stereophonic headphones at an average intensity of 69 dB SPL. Both cassette units were serviced immediately prior to the experiment so that the heads on both units were aligned. Intensity levels were calibrated with a Realistic Portable Sound Level Meter (A scale, fast response rate).

The stimuli were presented at the rate of 3 pairs per 2 seconds, with an average trial separation in intervals of 10 seconds (Bartz, Satz, and Fennell, 1966; Pohl, 1979). Of the sixty experimental subjects, 95% showed a right ear advantage on the standard dichotic listening test.

Group-specific taped instructions for the IID dichotic listening test were provided immediately following the standard dichotic listening test. Once the examiner was satisfied that the subject had understood the taped instructions, the subject was provided with eight blocks of practice stimuli (four to each ear) in order to acquire a fast response set (Appendix G).

A computer routine scored each practice block after it had been presented to both ears (Appendix H). During the scoring period, subjects were instructed to complete the Coren-Porac Sensory Motor Survey II (Coren, Porac, and Duncan, 1979; Porac and Coren, 1981) (Appendix I), and a modified version of the Annett Handedness Questionnaire (Annett, 1970) (Appendix J). Only subjects who showed a right-sided preference on either measure were included in the study (Bryden, 1982; 1975; Curry, 1967; Zurif, & Bryden, 1969). Of the 60 participants who were administered the handedness and lateral preference questionnaires, none were excluded from the study because of equivocal right-sided lateral preference on both measures.

Subjects

Sixty neurologically intact, unilingual, anglophone, right-handed males between the ages of 18 and 30 were recruited as paid participants by classroom announcements and posters. All participants were right-handed as determined by self-report inventories. All participants had normal hearing; defined as no pure tone audiometric hearing threshold greater than 10dB at 500, 1000, 2000, or 4000 Hz, and no interaural pure tone discrepancy greater than 10 dB for the same frequencies.

Materials

Thirty-six monosyllabic target words of equal frequency of occurrence in the English language were selected from the norms of Kucera & Francis (1967) and rated for imageability and emotionality by a class of undergraduate students using the same procedure outlined by Pavio, et al., (1968) (Appendix K). These ratings served as a priori semantic classification criteria for creating three semantic categories: (a) abstract, (b) concrete, and (c) emotional. The target words were paired with neologisms (i.e., easily pronounceable non-words) of equal length and identical initial phoneme (Appendix L). A tape composed of these stimuli was prepared using a female voice. The taped stimuli were played through a bandpass filter (150-3800 Hz), digitized (12 bit resolution at 8,000 samples per second) using an analog to digital converter (Data-Translation

2801-A), and stored in computer memory for later reproduction as 36 dichotic pairs using a digital to analog converter (Data-Translation 2801-A). A random generation program stored within computer memory insured that the 36 dichotic pairs were presented randomly order to each ear for each block. An additional set of ten similarly paired stimuli was prepared for practice trials, and contained no stimuli used in the actual data collection.

Design and Procedure

The experiment had three levels of stimulus factor (i.e., abstract, concrete, and emotional), and two levels of response factor (i.e., verbal vs. nonverbal). The dependent variable was interaural intensity difference (IID). Repeated measurements on the dependent variable were conducted for every level of the stimulus factor for each subject.

In alternating blocks, subjects were told to attend to only one ear and to make a semantic classification decision as to the semantic category (i.e., abstract, concrete, or emotional) of the target word heard in the ear they had been instructed to attend to. Single dichotic pairs consisting of a target word to the attended ear and a neologism to the unattended ear were presented and the subject made his semantic classification immediately after the stimuli were presented. Subjects were not told that a neologism would be presented to the unattended ear.

Manual responders had one second to press with their left hand, one of three telegraph keys that corresponded to their semantic classification. Verbal responders had two seconds to report the semantic category of the target word. This allowed a blind examiner enough time to enter the verbal responders' decisions by pressing the corresponding telegraph key. Prior testing of the blind examiner's response times (Appendix M) determined that a two second latency accorded verbal responders as much, if not more time as manual responders with which to make their semantic classifications. For both groups, responses which were not entered within the allotted time frame were scored as errors by the computer, which delivered a beep, heard by the subject over a loudspeaker placed on table facing him. Each subject was trained to recognize the beep as a signal that his response rate was too slow and that he should make his classifications more rapidly. A scoring routine in computer memory classified all other responses as either correct or incorrect on basis of a priori stimulus category ratings by the cohort group.

After the eight practice blocks, all subjects had learned the task requirements sufficiently well to be able to make the classification decisions within the allotted time frame. Each subject was then provided with a break. During the pause, subjects were asked to complete Form C of the

Sixteen Personality Factor (16 P-F) Questionnaire (Cattell, Eber, and Tatsuoka, 1970; Institute for Personality and Ability Testing, 1972).

After approximately ten minutes, subjects were asked to resume the experiment and were presented with the experimental stimuli. Eight blocks of each stimulus type were presented in alternating order to each ear. After each block, the computer scored the subject's performance and headphones were reversed for the upcoming block. During this scoring period subjects were asked to continue working on the 16 P-F. After all eight blocks of experimental stimuli were presented and scored, and before being discharged, subjects were debriefed and their questions were answered.

The experiment was completely counterbalanced. Half the subjects were tested with verbal report as the mode of response, and the experimenter entered the response by pressing the keys. Half the subjects were tested with a non-verbal (manual) mode of response, and pressed the keys themselves. Within each response group, half the subjects first heard the target words with the right ear and half with the left ear. Subjects were randomly assigned to either the verbal response group or the manual response group according to a Latin Squares procedure (Kirk, 1968).

The masks (neologisms) were presented at a constant sound pressure level (SPL) of 60 dB. Each ear first heard the target words at 60 dB, unless the overall accuracy on the

practice blocks was less than or equal to 40%, or greater than or equal to 60%, which resulted in the initial targets being presented at 57 dB or 63 dB, respectively. On subsequent experimental blocks, the intensity of the target stimulus was adjusted up or down by 3 dB for each ear independently, depending on whether the subject had incorrectly or correctly classified the semantic category of the stimulus on the preceding block for that ear. Similar adjustments were made in increments or decrements of 6 dB if the subject performed identically for both ears. This resulted for each subject, and each ear, a signal to noise ratio, interaural intensity difference (IID), for each dichotic pair in each condition. Graves and Marcopulos (1985) have reported that the procedure tends to converge on an accuracy of approximately 50% for each stimulus for each ear. The average of the right minus left intensities of the last presentation of the 12 stimulus pairs of a category provides the measure of ear advantage. A positive difference represents a right ear advantage (REA) corresponding to accurate classification from the right ear at a lower target intensity than for classification from the left ear for the same target. The statistics for the 36 difference scores (real words only) provide a mean ear asymmetry IID for each individual subject and condition. This dependent variable was obtained as three (repeated) measures for each subject (i.e., abstract, concrete, and emotional words).

RESULTS

Overall IID

Table 2 summarizes the data from block 4 of the experimental procedure and in terms of each mode of response. A summary of means and standard deviations from other data collected (audiometric test, standard DL, personality scales, etc.) can be found in Appendix N. All statistical analyses were based on data derived from the last block (i.e., block 4 only) of the experimental procedure, because it alone provides a summary of the subject's overall performance throughout the experiment. On the basis of the mean total IID (i.e., RLDIFFTO) it is apparent that regardless of response mode, an overall REA was elicited by the procedure. Two-tailed testing confirmed that the overall REA (i.e., collapsed across stimulus type and modes of response) was significantly different from zero: $\bar{M} = 0.878$ dB, $t(59) = 4.457$, $p < .001$. The REA for both verbal ($\bar{M} = 0.972$ dB) and manual ($\bar{M} = 0.783$ dB) response modes was also significantly different from zero: $t(29) = 4.765$, $p < .001$ and $t(29) = 2.296$, $p < .01$, respectively.

Figure 1 highlights the pattern of attenuation corresponding to each stimulus type and mode of response. Figure 2 illustrates the pattern of ear asymmetry in average attenuation for each type of stimulus, as well as the overall pattern collapsed across stimulus types.

Table 2

Means and Standard Deviations of Verbal and Manual Responders for the Experimental Procedure.

	TOTAL (N=60)		VERBAL (n=30)		MANUAL (n=30)	
	M	S.D.	M	S.D.	M	S.D.
RAVEATT1	22.68	7.40	25.16	7.74	20.20	6.24
LAVEATT1	21.10	7.50	24.34	7.70	17.87	5.78
RAVEATT2	37.23	5.68	38.38	5.32	36.09	5.89
LAVEATT2	36.37	5.91	37.39	5.57	35.34	6.16
RAVEATT3	20.63	8.67	22.94	8.09	18.32	8.75
LAVEATT3	20.45	8.33	21.83	7.94	19.07	8.61
RAVEATT	26.85	5.61	28.83	5.28	24.87	5.30
LAVEATT	25.97	5.45	27.85	5.36	24.09	4.94
AVEATT1	21.89	7.35	24.75	7.64	19.03	5.87
AVEATT2	36.80	5.71	37.88	5.36	35.72	5.92
AVEATT3	20.54	8.42	22.38	7.96	18.69	8.58
RLDIFF1	1.58	2.47	0.82	2.12	2.33	2.58
RLDIFF2	0.87	2.04	0.98	1.92	0.75	2.18
RLDIFF3	0.18	2.40	1.12	1.82	-0.75	2.57
RLDIFFT0	0.88	1.53	0.97	1.12	0.78	1.87

Note: RAVEATT1=Right average attenuation for stimulus type 1 (abstract); LAVEATT1=Left average attenuation for stimulus type 1 (abstract); RAVEATT2=Right average attenuation for stimulus type 2 (concrete); LAVEATT2=Left average attenuation for stimulus type 2 (concrete); RAVEATT3=Right average attenuation for stimulus type 3 (emotional); LAVEATT3=Left average attenuation for stimulus type 3 (emotional); RAVEATT=Right average attenuation across all 3 stimulus types $(RAVEATT1+RAVEATT2+RAVEATT3/3)$; LAVEATT=Left average attenuation across all 3 stimulus types $(LAVEATT1+LAVEATT2+LAVEATT3/3)$; AVEATT1=Average attenuation across both ears for stimulus type 1 (abstract); AVEATT2=Average attenuation across both ears for stimulus type 2 (concrete); AVEATT3=Average attenuation across both ears for stimulus type 3 (emotional); RLDIFF1=Interaural intensity difference of stimulus type 1 $(RAVEATT1-LAVEATT1)$; RLDIFF2=Interaural intensity difference of stimulus type 2 $(RAVEATT2-LAVEATT2)$; RLDIFF3=Interaural intensity difference of stimulus type 3 $(RAVEATT3-LAVEATT3)$; RLDIFFT0=Mean total interaural intensity difference across all stimulus types.

FIGURE 1
Average Attenuation in verbal & manual responders for each stimulus type and collapsed across stimulus types (combined)

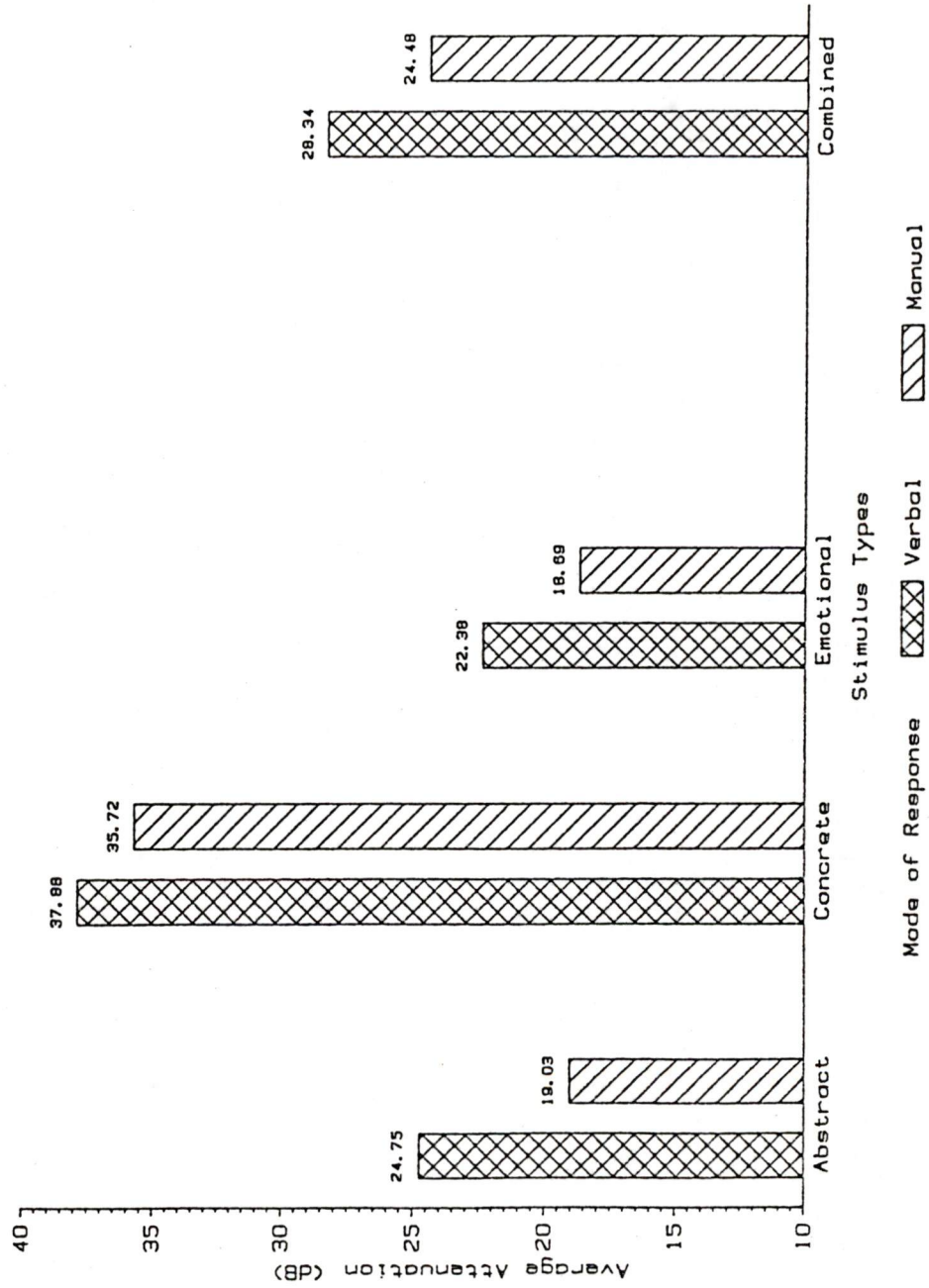


FIGURE 2
 Left and Right Ear Average Attenuation in verbal and manual responders
 for each stimulus type and collapsed across stimulus types (combined)

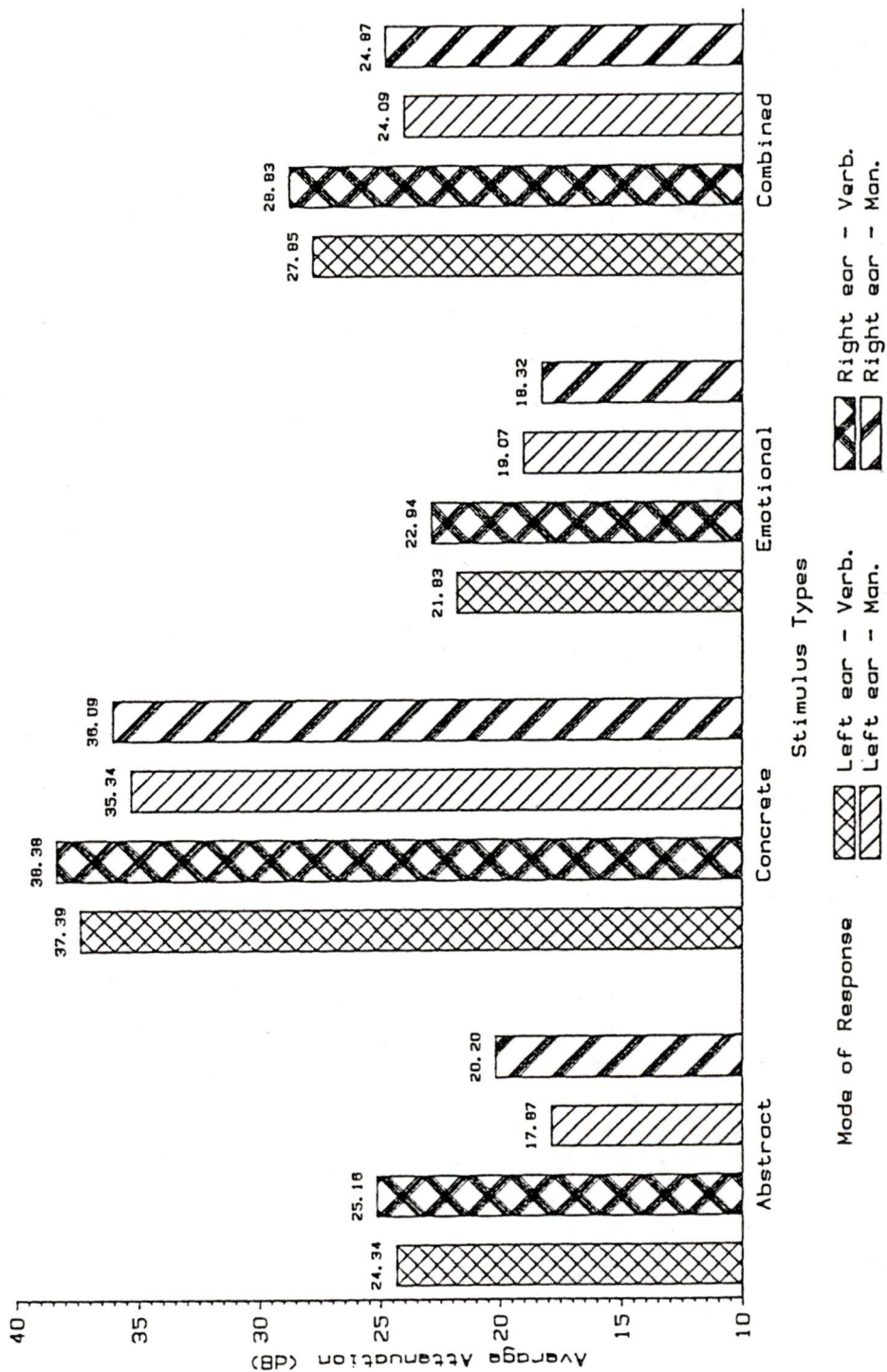


Figure 3 demonstrates that the IID procedure is a difference score of the average attenuation between right and left ears (i.e., signal to noise ratio).

Although verbal responders showed a greater overall REA (collapsed across stimulus type) than manual responders, a multivariate repeated measures analysis of variance (MANOVA) of the mean total IID showed that mode of response alone did not introduce significant variance in the REA effect:

$F(1,56) = .316, p < .576$. However, a significant main effect for stimulus category on overall ear asymmetry (i.e., RLDIFFTO) was found confirming the hypothesis that stimulus type contributes considerably to ear asymmetry variance:

$F(2,55) = 6.633, p < .003$. Figure 4 illustrates the linear trend to this pattern and shows that only abstract words were able to elicit significant REAs (collapsed across response modality).

An unexpected finding was that order of target presentation produced a significant main effect of initial target ear on the mean total IID: $F(1,56) = 23.018, p < .001$. A significantly greater overall REA was elicited if the left ear ($M = 1.683$ dB) rather than the right ear ($M = 0.072$ dB) received the target series first. Figure 5 illustrates the pattern of this effect on overall IID, and for each stimulus type. This nuisance variable did not interact significantly with either mode of response nor stimulus type.

FIGURE 3
Interaural Intensity Difference (IID) in verbal & manual responders for each stimulus type and collapsed across stimulus types (combined)

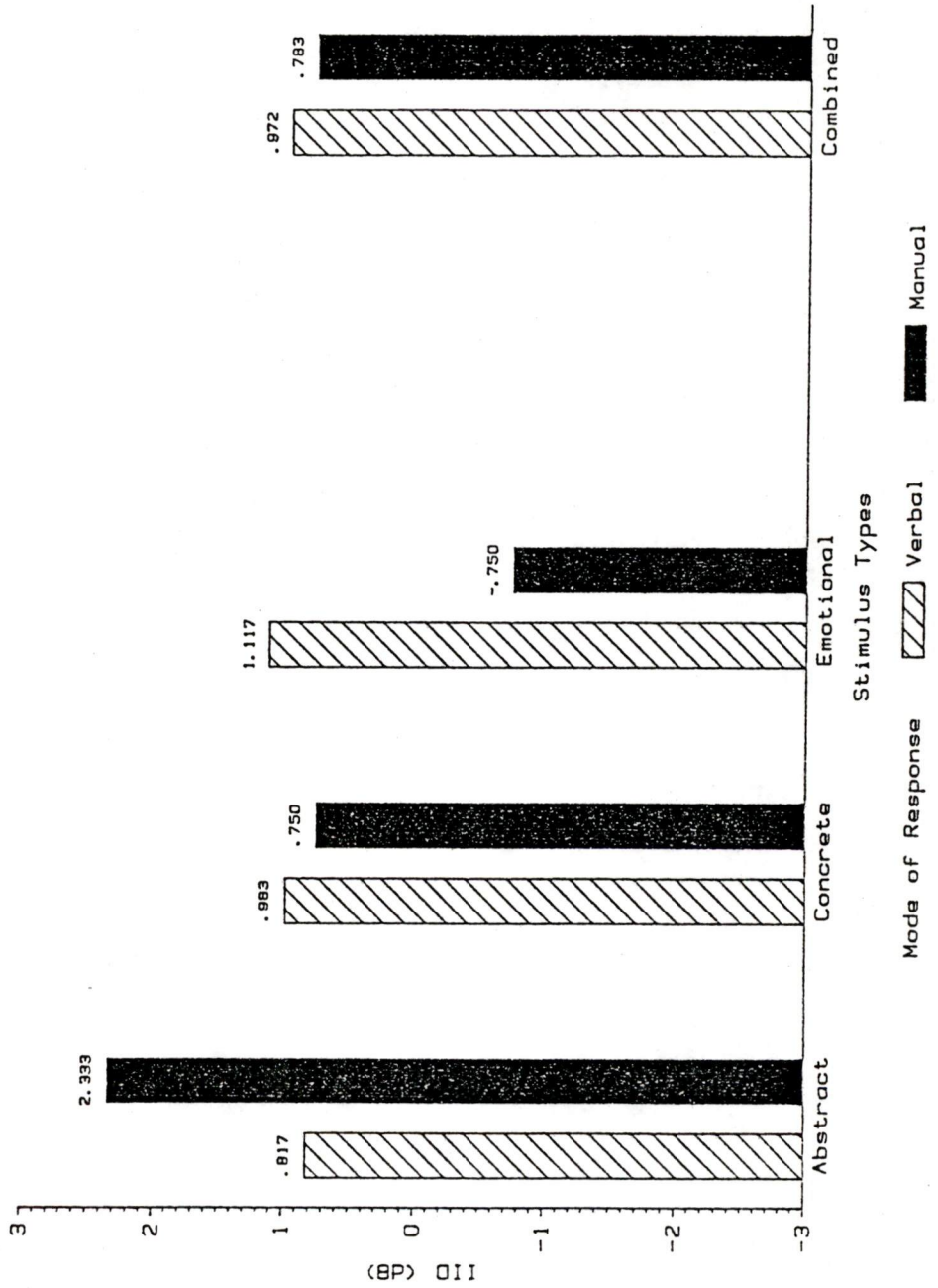


FIGURE 4
Interaural Intensity Difference (IID) for each stimulus type
collapsed across mode of response (verbal & manual)

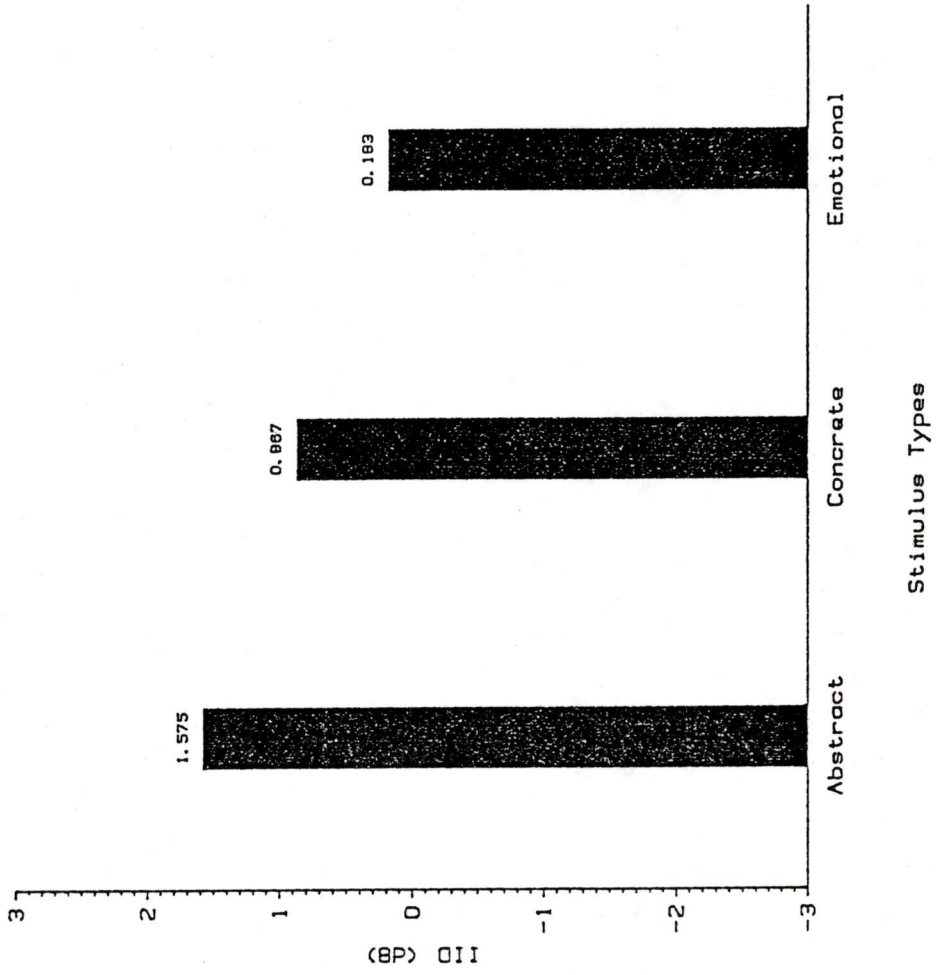


FIGURE 5
Interaural Intensity Difference (IID) in right & left initial target ears for each stimulus type and collapsed across stimulus types (combined)

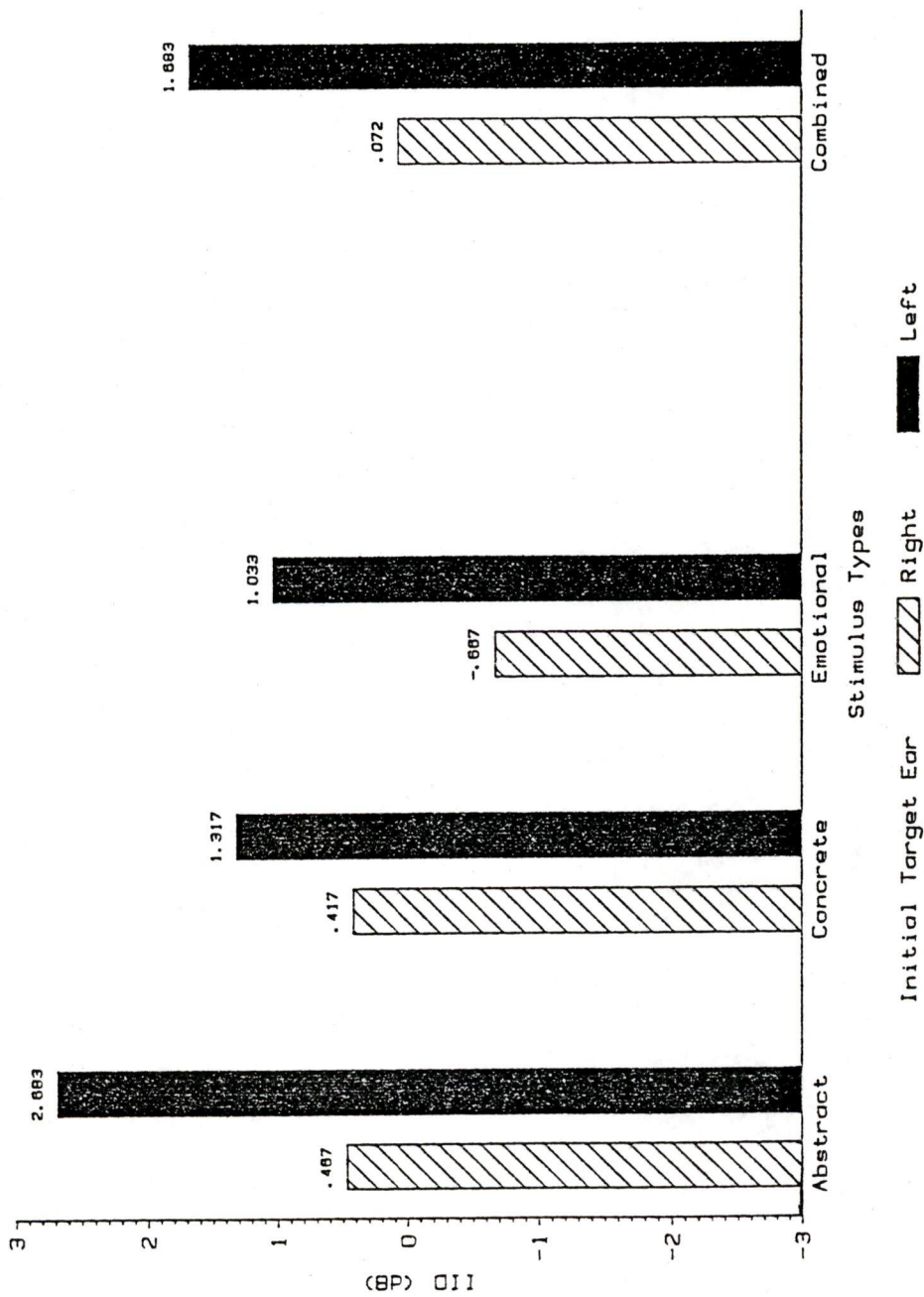


Table 3 summarizes the results of this analysis, while Figure 6 shows this general pattern of attenuation for each stimulus type and overall in relation to the initial ear of target presentation.

IID for Each Stimulus Category

A multivariate repeated measures analysis of variance (MANOVA) performed on the IID measures of each stimulus category confirmed the hypothesis that the three stimulus types contributed differentially to ear asymmetry variance (Table 4). A significant main effect for stimulus category $F(2,55) = 6.633, p < .003$ also was found. The hypothesis that this trend would have a quadratic component (i.e., that concrete and emotional words would be approximately equal in their IID values) was not confirmed. Rather, stimulus type produced a significant linear trend $F(1,56) = 13.497, p < .001$, with abstract words producing the greatest positive IID and emotional words the smallest. Figure 4 illustrates the pattern of this significant main effect for stimulus type. Overall, the differential contribution of each stimulus type (collapsed across modes of response) was remarkable; abstract words elicited the greatest ear asymmetry variance ($M = 1.575$ dB), $t(59) = 4.953, p < .001$, followed by concrete words ($M = 0.867$ dB), $t(59) = 3.297, p < .01$, while emotional words elicited a non-significant REA ($M = 0.183$ dB), $t(59) = .590, p > .20$.

Table 3

Repeated Measures MANOVA
Multivariate test of significance - IID.

SOURCE	SS	DF	MS	F	SIG. OF F
WITHIN CELLS	94.72159	56	1.69146		
STIMTYPE	46.23021	1	46.23021	27.33159	.001
RESPMODE	.53487	1	.53487	.31622	.576
FIRSTEAR	38.93464	1	38.93464	23.01841	.001
RESPMODE BY FIRSTEAR	3.58633	1	3.58633	2.12026	.151

FIGURE 6
Average Attenuation in right & left initial target ear for each stimulus type and collapsed across stimulus types (combined)

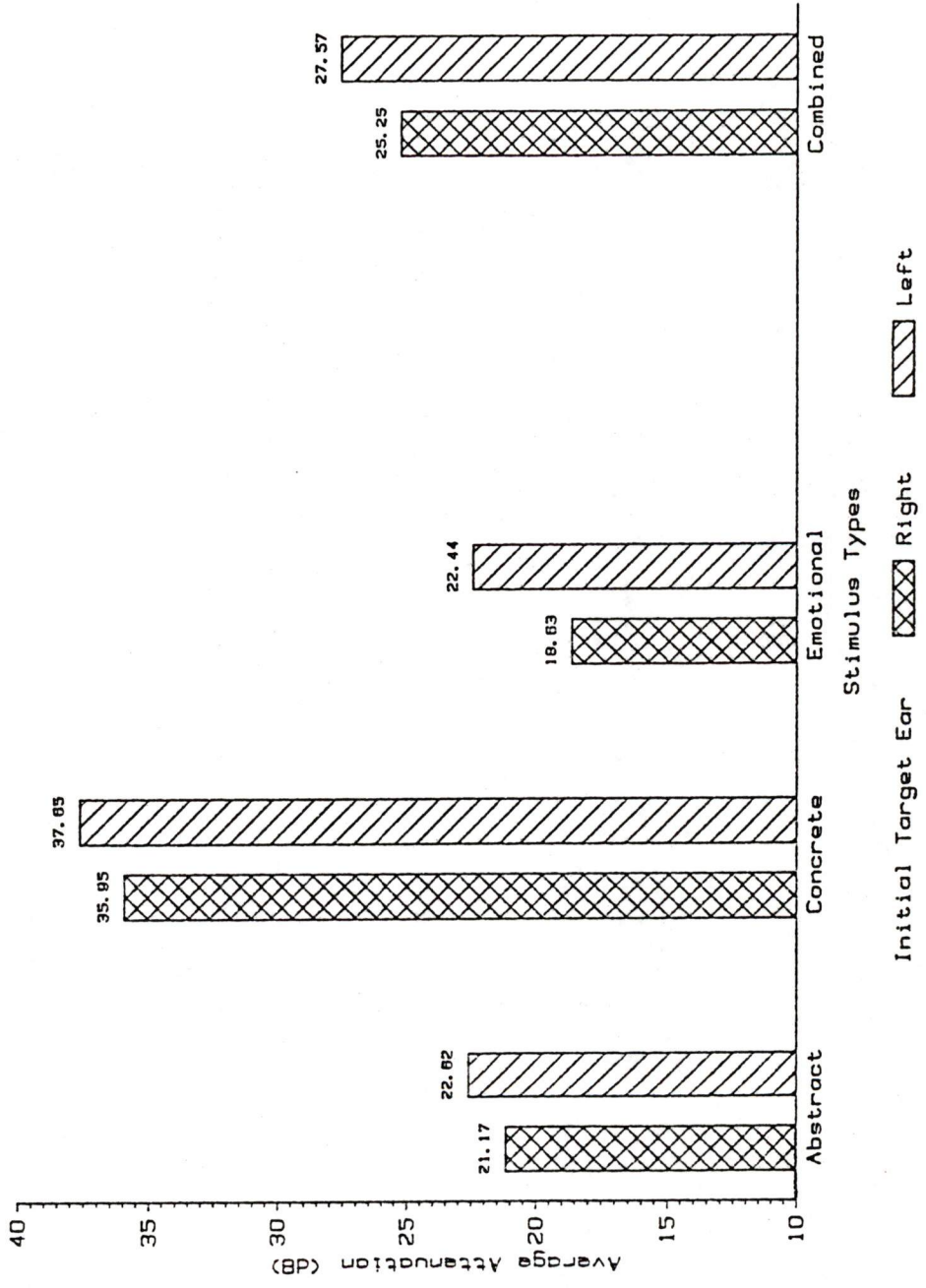


Table 4

Repeated Measures MANOVA
Main Effects for Stimulus Type, and Interaction Effects (IID).

I. EFFECT ... STIMTYPE

MULTIVARIATE TEST OF SIGNIFICANCE

TEST NAME	VALUE	APPROX. F	HYPOTH. DF	ERROR DF	SIG. OF F
Wilks	.80568	6.63253	2.00	55.00	.003

UNIVARIATE F-TESTS WITH (1,56) D.F.

VARIABLE	HYPOTH. SS	ERROR SS	HYPOTH. MS	ERROR SS	F	SIG. OF F
LINEAR	58.10208	241.06667	58.10208	4.30476	13.49717	.001
QUADRAT	.00625	186.91111	.00625	3.33770	.00187	.966

II. EFFECT ... RESPMODE BY STIMTYPE

MULTIVARIATE TEST OF SIGNIFICANCE

TEST NAME	VALUE	APPROX. F	HYPOTH. DF	ERROR DF	SIG. OF F
Wilks	.73713	9.80692	2.00	55.00	.001

UNIVARIATE F-TESTS WITH (1,56) D.F.

VARIABLE	HYPOTH. SS	ERROR SS	HYPOTH. MS	ERROR SS	F	SIG. OF F
LINEAR	85.85208	241.06667	85.85208	4.30476	19.94351	.001
QUADRAT	.03403	186.91111	.03403	3.33770	.01019	.920

Table 4 (continued)

Repeated Measures MANOVA
Main Effect for Stimulus Type, and Interaction Effects (IID).

III. EFFECT ... FIRSTEAR BY STIMTYPE

MULTIVARIATE TEST OF SIGNIFICANCE

TEST NAME	VALUE	APPROX. F	HYPOTH. DF	ERROR DF	SIG. OF F
Wilks	.93556	1.89407	2.00	55.00	.160

UNIVARIATE F-TESTS WITH (1,56) D.F.

VARIABLE	HYPOTH. SS	ERROR SS	HYPOTH. MS	ERROR SS	F	SIG. OF F
LINEAR	2.00208	241.06667	2.00208	4.30476	.46509	.498
QUADRAT	11.20069	186.91111	11.20069	3.33770	3.35581	.072

IV. EFFECT ... RESPMODE BY FIRSTEAR BY STIMTYPE

MULTIVARIATE TEST OF SIGNIFICANCE

TEST NAME	VALUE	APPROX. F	HYPOTH. DF	ERROR DF	SIG. OF F
Wilks	.98974	.28514	2.00	55.00	.753

UNIVARIATE F-TESTS WITH (1,56) D.F.

VARIABLE	HYPOTH. SS	ERROR SS	HYPOTH. MS	ERROR SS	F	SIG. OF F
LINEAR	1.10208	241.06667	1.10208	4.30476	.25601	.615
QUADRAT	1.05625	186.91111	1.05625	3.33770	.31646	.576

Verbal responders showed REA's that were significantly greater than zero for each stimulus category: abstract ($M = .8167$ dB), $t(29) = 2.105$, $p < .05$; concrete ($M = .9833$ dB), $t(29) = 2.809$, $p < .01$; emotional ($M = 1.117$ dB), $t(29) = 3.354$, $p < .01$. In contrast to this pattern, manual responders demonstrated an REA that was significantly different from zero only for abstract words ($M = 2.333$ dB), $t(29) = 4.95$, $p < .001$; the REA for concrete words ($M = 0.750$ dB) and the LEA for emotional words ($M = -0.750$ dB) were not significantly different from zero, $t(29) = 1.889$, $p > .20$ and $t(29) = 1.599$, $p > .20$, respectively.

The hypothesis that task demands (i.e., stimulus type and response modality) contribute to ear asymmetry variance was confirmed. A significant mode of response by stimulus category interaction was found $F(2,55) = 9.807$, $p < .001$, indicating again a linear trend. No other interactions reached significance.

Post-hoc analyses (Tukey's honestly significant difference test) conducted on the main effect for stimulus type revealed that only abstract and emotional words were significantly different from each other, $q(3,116) = 4.77$, $p < .01$. Analysis of simple main effects disclosed that verbal responders differed significantly from manual responders on two stimulus categories: abstract $q(58,116) = -3.70$, $p < .05$, and emotional $q(58,116) = 4.55$, $p < .01$ words.

Table 5 summarizes these analyses.

Post-hoc analysis (Scheffe test) of the stimulus type by response mode interaction revealed that the manual response group alone accounted for the interaction with a significant linear trend in stimulus category (abstract, concrete, emotional), $F(3, 116) = 27.9273$, $p < .01$. Verbal responders showed no substantive differences between stimulus types (Table 6).

Figure 7 summarizes the experimental data, and displays the confidence intervals.

Classification

Overall, the standard DL procedure correctly classified more participants as having an REA (95%) than did the IID procedure (78%). However, the IID procedure's relatively poor classification of REA was clearly an artifact of the main effect for initial ear of target presentations. When the classification of REA was based on IID broken down by the nuisance variable (i.e., initial ear), it was found that of the participants who initially heard the target series in the left ear the IID procedure classified 100 % as having an REA. Correspondingly, 100% of participants who showed a LEA had initially heard the target series in their right ear. Individual scores for the standard DL and the IID procedures are listed in Appendix O.

Table 5
 Post Hoc Analyses for IID - Simple Main Effects,
 and Main Effect.

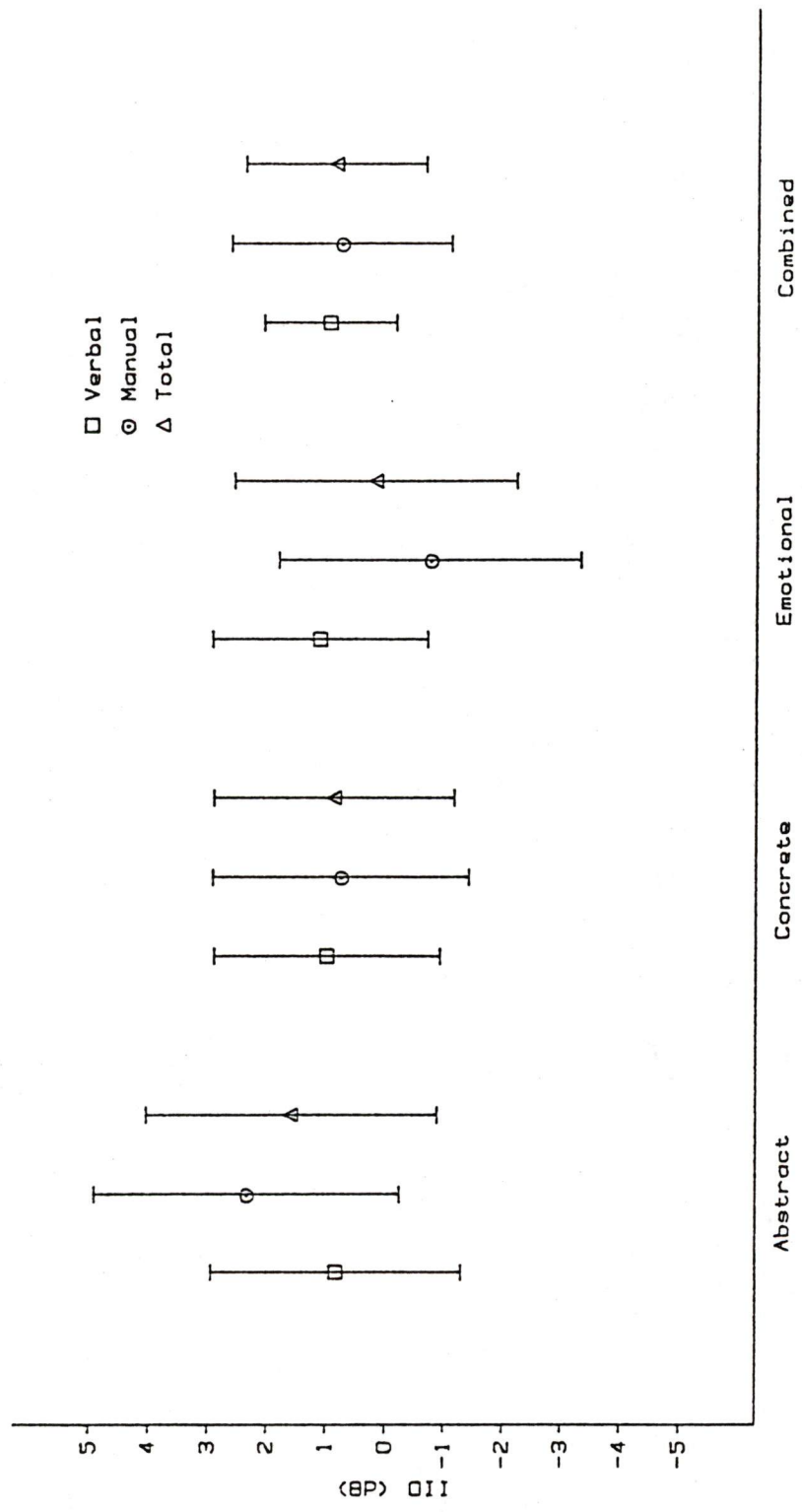
Variables	n	M	q	DF	SIGN.
SIMPLE MAIN EFFECT					
Abstract	Verbal	30	0.817	58,116	.05
	Manual	30	2.333		
Concrete	Verbal	30	0.983	58,116	n.s.
	Manual	30	0.750		
Emotional	Verbal	30	1.117	58,116	.01
	Manual	30	-0.750		
STIMTYPE MAIN EFFECT					
Abstract		60	1.575	3,116	n.s.
Concrete		60	0.867		
Abstract		60	1.575	3,116	.01
Emotional		60	0.183		
Concrete		60	0.867	3,116	n.s.
Emotional		60	0.183		

Table 6
 Post Hoc Analyses for IID - Interaction Effect.

ABSTRACT vs CONCRETE vs EMOTIONAL

Variables	n	trend	F	DF	SIGN.
Verbal	30	linear	0.264	3,116	n.s.
		quadr.	0.001	3,116	n.s.
Manual	30	linear	27.927	3,116	.01
		quadr.	0.007	3,116	n.s.

FIGURE 7
Interaural Intensity Difference in verbal, manual, and total group for each stimulus type, and collapsed across stimulus types (combined)



(Confidence Intervals Displayed)

Accuracy

Table 7 summarizes the analyses of overall accuracy data (derived from experimental block 4 only), and shows that both stimulus type $F(1,56) = 1783.434$, $p < .001$, and mode of response $F(1,56) = 4.287$, $p < .043$ affected accuracy, though no substantial difference in overall accuracy was apparent between verbal ($M = 6.83$, $S.D. = 1.19$), and manual ($M = 6.20$, $S.D. = 1.20$) responders, respectively. Post-hoc analyses (Tukey's Honestly Significant Difference Test) revealed that accuracy ratios varied considerably as a function of stimulus category. The pairwise comparisons are summarized in Table 8. Concrete words produced significantly greater accuracy ratios than abstract $q(3,116) = -9.58$, $p < .01$, or emotional $q(3,116) = 12.51$, $p < .01$ words, while abstract and emotional words produced no significant difference in overall accuracy $q(3,116) = 2.93$, $p > .05$. Appendix P summarizes the accuracy data.

Personality

Table 9 highlights the correlation analyses. The extraversion and neuroticism personality factors did not correlate significantly with the standard DL score, nor with the IID score. Only the lateral preference questionnaire of Coren & Porac and Duncan (1979) revealed a significant correlation with the IID score $r(60) = .3400$, $p < .008$. It did not, however, correlate with the handedness questionnaire of Annett.

Table 7

Repeated Measures MANOVA
Multivariate Test of Significance - Accuracy.

SOURCE	SS	DF	MS	F	SIG. OF F
WITHIN CELLS	79.97385	56	1.42810		
STIMTYPE	2546.93020	1	2546.93020	1783.43418	.001
RESPMODE	6.12269	1	6.12269	4.28728	.043
FIRSTEAR	2.46713	1	2.46713	1.72756	.194
RESPMODE BY FIRSTEAR	0.21400	1	0.21400	0.14985	.700

Table 8

Post Hoc Analyses for Accuracy - Main Effect.

Variables	n	M	q	DF	SIGN.
Abstract	60	0.540	-9.58	3,116	.01
Concrete	60	0.762			
Abstract	60	0.549	22.93	3,116	n.s.
Emotional	60	0.472			
Concrete	60	0.762	12.51	3,116	.01
Emotional	60	0.472			

Table 9

Pearson Correlation Coefficients for Dichotic Listening Score, Mean Total Interaural Intensity Difference, Lateral Preference Questionnaires and Personality Scales in Verbal and Manual Responders.

	TOTAL (N=60)		VERBAL (n=30)		MANUAL (n=30)	
	r	p	r	p	r	p
DLSCORE /						
EYSENCKE	.12	(.343)	.31	(.095)	.01	(.966)
EYSENCKN	.10	(.449)	.13	(.500)	.04	(.813)
LATPREFA	.05	(.732)	.08	(.687)	.06	(.757)
LATPREFC	.07	(.609)	.12	(.522)	.03	(.866)
RLDIFFTO	.04	(.790)	.03	(.863)	.02	(.897)
RLDIFF1	-.11	(.382)	-.01	(.969)	-.15	(.420)
RLDIFF2	.07	(.615)	-.01	(.951)	.15	(.439)
RLDIFF3	.14	(.303)	.08	(.669)	.10	(.612)
RLDIFFTO /						
EYSENCKE	-.04	(.752)	.16	(.387)	-.13	(.479)
EYSENCKN	.06	(.658)	-.34	(.066)	.28	(.134)
LATPREFA	-.17	(.198)	-.05	(.796)	-.23	(.216)
LATPREFC	.34	(.008)**	.56	(.001)***	.23	(.213)
LATPREFC /						
EYSENCKE	.12	(.368)	.14	(.471)	.03	(.868)
EYSENCKN	-.16	(.219)	-.26	(.160)	-.03	(.855)
LATPREFA	.12	(.381)	.01	(.963)	.20	(.283)
LATPREFA /						
EYSENCKE	.03	(.791)	-.16	(.393)	.14	(.474)
EYSENCKN	-.15	(.241)	-.05	(.812)	-.24	(.207)

Note: ** $p < .01$; *** $p < .001$; DLSCORE=Dichotic Listening ratio (R-L/R+L x 100); RLDIFF1=Interaural intensity difference of stimulus type 1 (RAVEATT1-LAVEATT1); RLDIFF2=Interaural intensity difference of stimulus type 2 (RAVEATT2-LAVEATT2); RLDIFF3=Interaural intensity difference of stimulus type 3 (RAVEATT3-LAVEATT3); RLDIFFTO=Mean total interaural intensity difference (IID); LATPREFC=Lateral Preference Survey of Coren & Porac; LATPREFA=Handedness Questionnaire of Annett; EYSENCKE=Extroversion scale of the Eysenck Personality Inventory; EYSENCKN=Neuroticism scale of the Eysenck Personality Inventory.

The Handedness Questionnaire of Annett (1970) and the standard DL test did not correlate significantly with the IID procedure.

DISCUSSION

The experimental hypotheses were confirmed. The analyses of the ear advantage variance distribution showed that the IID procedure is capable of demonstrating the left hemisphere's superior efficiency at speech processing in general, while providing evidence that the right hemisphere is also capable of making semantic decisions with regard to emotional words. However, this may only be evidenced when the mode of response does not induce a left-hemisphere bias. Similarly, but to a lesser degree, the right hemisphere also seems capable of making semantic decisions about highly imageable or concrete words.

Apparently, words that elicit multisensory and/or emotional experiences can enhance right-hemisphere speech processing ability in the absence of the verbal response bias favoring left-hemisphere dominance. In fact, it may be necessary to induce a right-hemisphere priming bias in order to elicit substantive variance in REA asymmetry for language.

Moscovitch's (1983) contention that large differences in performance, irrespective of stimulus type, are suggestive of differential hemispheric performance at higher levels of processing, and that hemispheric differences are likely to be small on semantic tasks, because each hemisphere contributes in its own way to the task at hand, would appear to account for the considerably greater levels of attenuation required

to reduce the accuracy level for concrete words.

Thus, ceiling effects may be more easily obtained with concrete stimuli because they can be processed as efficiently with either hemisphere, which suggests that some central processing systems may be less amenable than others to systematic manipulation with some types of stimuli or via peripheral control over stimulus quality. This suggests that stimuli such as concrete words can be processed efficiently with either hemisphere. As such, the bi-hemispheric representation of concrete words might account for the fact that some authors have reported LEAs and LVF advantages with concrete stimuli whereas others have reported REAs and RVF advantages. The controversy in reported findings may be due to the relative ease with which concrete stimuli may be processed in the left or right hemisphere. When mode of response priming effects are considered in light of this, it is also conceivable that verbal report paradigms would find REAs or RVF advantages, whereas manual (especially left-hand) response paradigms would find LEAs or LVF advantages.

The preceding review of the literature also tends to confirm the hypothesis that the processing resource capacities for concrete words are greater because of bi-hemispheric representation, relative to abstract or emotional words. If this is the case, it is conceivable that in future applications of the IID paradigm, subjects would still require significantly greater levels of attenuation for

different but phonemically and semantically equivalent concrete words being presented only once in each block, relative to abstract or emotional words.

In contrast to the relatively high levels of attenuation required to control accuracy for concrete words in the IID paradigm, the fact that substantially lower levels of attenuation were required to control accuracy for abstract or emotional words, and thereby elicit ear asymmetries, would suggest that such stimuli represent different cognitive tasks on central processors and may involve, the left hemisphere more or less than the other, in the task of stimulus representation. As such, the fact that some types of stimuli may be processed less efficiently in one or the other hemisphere may limit the resource capacities in the hemisphere that dominates the mediation of some types of stimuli. In fact, the proposed postulate for a relative absence of bi-hemispheric stimulus representation may provide an operational definition of differential resource capacities for information processing in DL paradigms. Consequently, this would tend to be reflected in the relatively low levels of attenuation required to have experimental control over accuracy for abstract or emotional words. In contrast to this effect, the fact that relatively higher levels of attenuation were required to control accuracy for concrete words would suggest that the resource capacities within the brain are higher for concrete (i.e., highly imageable) types

of stimuli because they may be processed as efficiently in one hemisphere or the other and that bi-hemispheric stimulus representation facilitates the transfer of salient information specific to concrete stimuli from one hemisphere to the other.

However, in order for different word stimuli to elicit functionally different lateralized asymmetries, hemispheric priming may be necessary to induce the mediation and representation of such stimuli. This may account for the finding that in verbal responders, no substantive differences in REA emerged as a function of stimulus category, whereas for manual responders, a stimulus category effect was clearly apparent. The priming effects of a verbal mode of response may not only induce a left-hemisphere preference, but as Moscovitch (1983) has argued, it also appears to inhibit the right hemisphere with regard to linguistic functions. In light of this, it is not surprising that findings of right-hemisphere linguistic abilities with certain types of words were often not replicable. Replication attempts often did not control for the confounds of left-hemisphere priming (i.e., requiring a verbal report) and concomitant right-hemisphere suppressor effects. Consequently, evidence for the right-hemisphere's ability to process the semantic aspects of language has been occluded.

The finding that initial ear of target presentation resulted in a significant effect reflects an ever present

limitation of repeated measures designs; learning effects were clearly apparent here. All subjects who showed an REA had initially heard the target in the left-ear, while all subjects who showed an LEA had initially heard the target in the right-ear. Yet, only half of the subjects within each response-mode group initially heard the target in the right ear and half initially heard the target in the left.

Presumably, the task was sufficiently difficult and the initial-ear performance discrepancy difference great enough on Block 1 that this effect could not be overcome in four blocks of stimulus presentation. However, this effect is not of major relevance to the findings because it represents highly systematic error variance that did not interact with either mode of response nor with stimulus type. The finding of an initial-ear effect is very interesting, and stands in marked contrast to earlier applications of this procedure in which no initial-ear effects were reported when CV combinations were the stimuli used (Graves and Marcopulos, 1985; Graves, and Morley, 1986). The novel use of words in the IID paradigm has thus introduced unexpected learning effects resulting in systematic variance. Aside from a conceptual account for this effect (discussed above) there remains the question of achieving experimental control over this effect when one is not interested in it specifically, but rather, considers it a nuisance variable. One apparent solution to the problem of learning effects in future

applications of the IID procedure would be to present subjects with many more blocks of the same stimuli. Conceivably, if some types of stimuli (i.e., concrete words) are more easily processed in either hemisphere, they may require relatively more blocks of stimulus presentation to maintain accuracy at approximately 50%. However, this would necessarily lengthen the duration of the experiment to possibly as much as 2 hours, which might introduce fatigue or boredom as additional confounds.

Another apparent solution would be to present subjects with different, but phonemically and semantically equivalent target stimuli from each category in each block of stimulus presentation. The presentation of different targets in each new block should eliminate the initial ear learning effects that were apparent in this paradigm and reduce the high levels of attenuation required to control accuracy for concrete stimuli. However, Graves (personal communication, August 18, 1986) has suggested that the IID procedure would not work with equivalent forms of a stimulus category, because the procedure is based on controlling accuracy for the same stimulus over repeated presentations. Thus, although the presentation of different but phonemically and semantically equivalent targets might allow experimental control over initial ear-of-presentation effects and possibly even ceiling effects such as can be evidenced for concrete words, it is more likely that the cost for such control would

be too high in that it could invalidate the IID paradigm altogether. The investigator would be confounding IID control over accuracy with the presentation of novel stimuli in each block, with no way of teasing apart the respective effects of each factor. Graves prefers the use of more experimental blocks to control accuracy. The point raised by Graves is well taken, and presents an interesting dilemma with regard to future applications of the IID procedure when words are the chosen stimuli.

The issue that alternative stimuli would invalidate the procedure is not entirely clear and would appear to be not only one of producing semantically and phonemically equivalent targets for each block in each category, but also of conducting a series of investigations in order to determine empirically if the procedure still is valid with phonemically and semantically equivalent targets being presented alternatively in each block. One manner of achieving this would be to address the issue of differential resource limitations for different types of words. As mentioned above, if concrete words are in fact processed as efficiently with either hemisphere or if they may elicit relatively greater bi-hemispheric stimulus representation, whereas abstract and emotional words may involve different cognitive tasks that are more specific to the left and right hemispheres, respectively, as indicated by the higher levels of attenuation required to control accuracy for concrete

words, relative to abstract or emotional words, then it is conceivable that different, yet phonemically and semantically equivalent targets from the concrete category would still require significantly greater levels of attenuation to control accuracy, relative to phonemically and semantically equivalent, yet different words from abstract or emotional categories. If this were the case, one explanation might be that some types of stimuli have greater bi-hemispheric representation than others, which tend to have more lateralized representation. Furthermore, such a lateralization pattern may be relatively context dependent and may operate more or less as a function of response modality priming. The issue presents an interesting avenue for future research involving this paradigm.

A difficult problem arises with regard to ceiling effects, to which concrete words appear most susceptible. Such stimuli apparently are processed more efficiently than are abstract or emotional words. Concomitantly, accuracy for concrete words appears relatively unresponsive to considerable levels of attenuation once these highly imageable words have been identified. This suggests that the task is less difficult with this type of stimulus material. This finding is inconsistent with Kimura's (1968) report that familiarity with stimulus material does not contribute to the critical distinguishing characteristics of speech sounds, and suggests that with some types of stimuli, this may not be the

case. In light of this finding, the use of highly abstract words, or of CV combinations would be preferable if one wished to elicit more reliable indices of left-hemisphere speech dominance in different populations (e.g., left-handed males and females). Alternatively, one would load the IID procedure with concrete and emotional words if the desired goal were to establish the degree to which the right hemisphere contributes to speech processing. However, future applications of the IID procedure may require considerably larger sets of stimuli and more numerous blocks of stimulus presentations to overcome initial-ear effects.

The finding that personality measures generally did not correlate with either handedness or ear asymmetry indices (i.e., standard DL score, and IID score) of functional lateralization, may be due to a number of factors including: (1) Personality questionnaires may be generally insensitive to cognitive processing styles; (2) personality questionnaires may not be appropriate representative measures of field dependence/independence; (3) personality styles and cognitive styles may be orthogonal factors.

Regardless of the reasons, it is apparent that the personality measures used in this experiment did not correlate with ear asymmetry indices of lateralized function. The findings from the IID experiment were similar to those reported by Mohr (1982). In both instances, the findings of previous reports that personality styles such as extraversion

(e.g., Charman, 1979), or field dependence-independence (e.g., Dawson, 1972; Pizzamiglio, 1974; Pizzamiglio, and Cecchini, 1971) are related to lateralized function were not replicated.

GENERAL DISCUSSION AND SUMMARY

General Discussion

Lieberman, and colleagues (1967) have suggested that the REA in verbal report DL paradigms may be a function of an inherent bias created by the response mode; if dichotically presented stimuli are perceived primarily by the same motor-command signals as those responsible for producing speech, an REA would be expected. In verbal report DL paradigms, the verbal stimulus to the right ear would seem to have immediate access to the verbal output centers needed to respond, while the left ear stimulus would not, because for most subjects, the right hemisphere is mute.

The data from the IID experiment supports the hypothesis advanced by Liberman, and colleagues (1967); verbal report apparently induces auditory signals to be perceived in the same hemisphere where similar motor-command signals for the production of speech are found. Because the effects of this bias were diminished considerably by requiring subjects to respond nonverbally, it would appear that a bias operates in this manner only when verbal report is the response modality, and when the stimulus material has a low probability of eliciting alternative modalities of stimulus representation (i.e., abstract words, CV combinations, etc.), whereas stimuli that can elicit multisensory and/or emotional modes of experiencing may be capable of eliciting cognitive

processing in the right hemisphere with relative ease. Also, an alternative right-hemisphere bias may operate in conjunction with this phenomenon when an alternative response modality is required of the subject (i.e., manual response with the left hand).

If in DL paradigms requiring verbal report, the dichotic presentation of sounds that are specific to the speech production centers (e.g. sounds that can be articulated) are processed more efficiently in the hemisphere dominant for speech production, because the subject is required to report verbally, then this phenomenon may provide an operational definition for the postulate that left-hemisphere priming effects account for my findings and those of other investigators (e.g., Day, 1977, 1979; Graves et al., 1981; Hines, 1976; McFarland, et al., 1978) that abstract words can elicit significantly greater REAs than concrete or emotional words. Furthermore, priming effects may be interactive; stimulus type and/or mode of response may prime the left-hemisphere.

As additional indirect evidence for the hemispheric priming postulate, it is worthy of noting that in a DL paradigm involving real words and backward speech (interference) stimuli, Kimura (1968) failed to dissociate verbal report as a potential source of confound; she noted that subjects consistently attempted to articulate the backward speech material presented to the right ear despite

the fact that this proved excessively difficult for them to do. Perhaps the verbal report procedure she employed was priming the left hemisphere and producing a right-ear bias for the interference stimuli. The notion of hemispheric priming needs further investigation, but it does account well for a number of discrepant findings in the literature.

Various other characteristics of the verbal stimulus (e.g. prosody, melody, imageability, emotionality) may be processed as efficiently, if not more efficiently, by linguistic systems in the hemisphere that is non-dominant for speech production. There is mounting evidence that the non-dominant hemisphere may play a much more important mediating role in semantic processing than has heretofore been considered (Bryden and Ley, 1983; Butter & Norrsel, 1968; Day, 1977, 1979; Dimond, 1972; Gazzaniga, 1977; Graves et al., 1981; Kelly and Orton, 1979; Levy, 1974; McLoughlin & McLoughlin, 1983; McFarland et al., 1978; Teng & Sperry, 1973; Wapner, Hamby, & Gardner, 1981; Searleman, 1977, 1983). The issue thus appears to be one of establishing experimental procedures that continue to allow an unequivocal parsing of the various factors which contribute to ear asymmetry variance in DL paradigms. Based on the unequivocal findings derived from the IID experiment, mode of response and stimulus category appear to contribute considerably to this variance in right-handed males; this population is generally argued to be more lateralized for speech than others (Bryden,

1982; Corballis, 1983; Porac, and Coren, 1981). Ear asymmetry variance would be expected to be even greater in left-handed males, as well as right-handed and left-handed females than in the right-handed males who participated in this investigation.

With respect to the left ear "stimulus decay" hypothesis (Kimura, 1967; 1973), it may be that without adequate bi-hemispheric processing, a verbal stimulus that is not encoded for verbal or non-verbal output will rapidly decay. Thus, a left ear stimulus such as a consonant-vowel combination would have little information which could be usefully encoded by the right hemisphere, though a great deal of information with respect to what the left hemisphere's role in linguistic processing involves. Consequently, in a DL paradigm, a left ear stimulus of this type, without further processing in the right hemisphere, albeit waiting to be transferred to the left hemisphere for further encoding and verbal output, would be most subject to temporal decay. During the waiting-without-processing, and the subsequent transfer periods, some decay or degradation of the left ear signal would be expected to take place. The result would be an impairment in the accuracy of reporting left ear stimuli. This explanation also accounts for the slight LEA found in conditions of monaural stimulus presentation reported by Kimura (1967). In the absence of a stronger contralateral verbal stimulus with characteristics specific for

left-hemisphere processing, the left ear stimulus travels a direct route ipsilaterally to the left hemisphere and reaches the speech specific system with less degradation of the signal than does a right ear stimulus, which must traverse the commissures.

Furthermore, output responses may in fact lead to certain inhibitory effects, which occlude adequate processing of simultaneously presented stimuli specific to the linguistic processing capacities of the left hemisphere (Moscovitch, 1983). This may account for the IID experimental finding that manual responders showed significant differences in their REAs for various stimulus types, whereas verbal responders did not. Thus, in the standard DL experiments reported to date, processing and output functions may have been confounded, since subjects have been typically required to respond verbally, and usually to stimuli that carried information which may be encoded, processed, and articulated more efficiently by the left hemisphere; for example, consonant-vowel (CV) combinations (Lieberman et al., 1967; Shankweiler & Studdert-Kennedy, 1967; Studdert-Kennedy & Shankweiler, 1970), or backward speech (Kimura, 1968).

Verbal report DL paradigms that have generally ignored task demands may thus have made it relatively impossible to tease apart the respective roles played by each hemisphere in the semantic processing of linguistic stimuli.

The experiment presented in this investigation, however, was designed to separate processing and output functions, as well as, stimulus characteristics of the verbal stimuli in a DL paradigm. The aim of the experiment, to determine if the processing necessary for the perception of speech in the normal human brain is lateralized as a function of stimulus characteristics which concord with the lateralization of verbal output, or if the observed asymmetries in DL experiments do in fact reflect complete asymmetrical perceptual processes, appears to have been satisfied. Task demands would appear to contribute significantly to hemispheric asymmetry variance in a semantic processing task.

The IID experimental findings do not replicate those reported by Springer (1971). Using a search task, she too had attempted to dissociate the production-perception confound by requiring subjects to respond manually. However, the dichotic stimuli used by Springer were consonant-vowel (CV) pairs. She reported an REA on accuracy as well as in reaction time (RT) on this task.

In light of previous reports that RT measures produce extreme variance (e.g., Prior et al., 1984), reflecting perhaps extremes in varying overall performance (Graves, and Morley, 1986), Springer's (1971) finding of an REA in RT measures does not appear to provide a strong refutation of the hypothesis that mode of response and stimulus type (i.e., task demands) contribute significantly to hemispheric

asymmetry variance in a DL paradigm. However, the hypothesis that task demands may contribute to hemispheric asymmetry variance accounts well for Springer's (1971) findings. In fact, her data would appear to provide additional evidence indicating that linguistic processors specific to speech production are lateralized in the dominant hemisphere (Lieberman et al., 1967). The fact that Springer used CV pairs, stimuli whose characteristics may be specific to left-hemisphere processing, may have confounded the design, and induced an REA, because of the left hemisphere's dominance for the perception of such material. Thus, while Springer (1971) controlled in part for the confound of response mode she did not control for the confounding effects of stimulus characteristics priming left-hemisphere speech perception. As well, Springer's failure to find a significant hand by ear interaction effect (which approached significance) may have been due to the very small sample (N=8) investigated, and the fact that in all subjects, she counterbalanced the hands used to respond.

The IID procedure has demonstrated the importance of the confounding factors of task demands and priming effects, which emphasizes the point that previous investigations may not have provided unequivocal data with which to rule out the possibility that the right hemisphere apparently plays an important mediating role in semantic processing. In short, previous investigations may have confounded asymmetry for

speech perception with (1) speech production, and (2) stimulus characteristics, specific to the semantic processing systems lateralized in the hemisphere dominant for speech production.

In the present experiment, these confounds were controlled for by modifying the standard DL procedure such that it became a semantic decision task. As well, the verbal report confound was controlled for by adopting and modifying the response procedure used by Springer (1971). The rationale underlying the use of two response modes was that if verbal report induces a left-hemisphere bias, then a mode of response bias favoring a right-hemisphere bias might similarly be created (i.e., by manual response with the left hand). This would conceivably enable these subjects to respond to the dichotic presentations without engaging the verbal motor output centers of the left hemisphere, while engaging the motor output centers of the right hemisphere, thereby creating a right-hemisphere bias. Since each hemisphere is capable of initiating a contralateral manual response, any difference observed on the accuracy of correct semantic classification of left ear words as compared with right ear words would be attributable to a true processing asymmetry between the hemispheres. The result would be a greater positive IID for verbal responders than for non-verbal responders. Although mode of response alone did not appear to induce a sufficient hemispheric priming bias

capable of producing substantive ear asymmetry variance, it did interact with stimulus type, and in such instances, produced considerable ear asymmetry variance. This finding supports Haggard and Parkinson's (1971) contention that task demands are important determinants of ear asymmetries.

The Role of the Right Hemisphere in Imagery and Affect

This experiment corroborates previous reports that the right hemisphere plays an important role in dealing with emotions (Bryden, and Ley, 1983; Bryden, Ley, and Sugarman, 1982; Graves et al., 1981; Ley and Bryden, 1979; Moscovitch, 1983) and high imagery words (Bradshaw and Gates, 1978; Bryden and Ley, 1983; Day, 1977, 1979; Ellis and Sheppard, 1974; Hines, 1976, 1977; Kelly and Orton, 1979; McFarland et al., 1978). However, some investigations have reported no differences between high imageability (i.e., concrete) and low imageability (i.e., abstract) words (Hatta, 1977; Prior et al., 1984; Saffran Bogyo, Schwartz, and Marin, 1980).

Bryden and Ley's (1983) priming hypothesis may account for findings such as those I have reported. Priming may function in terms of the task demands and/or bi-hemispheric lexical representations of concrete and emotional words. The priming component would provide one manner of accounting for some of the shortcomings of Kinsbourne's (1973, 1975) attentional bias model. The IID experiment data appear to support Bryden and Ley's (1983) argument that Kinsbourne's (1973, 1975) model is incorrect in its general assertion that

verbal thinking activates only the left hemisphere (Bryden and Ley, 1983). Rather, it would appear that under certain conditions (e.g., verbal mode of response), only the left hemisphere is primed, while under different conditions (e.g., manual mode of response) right-hemisphere priming effects may be observed for some types of verbal material such as emotional words. Kinsbourne's attentional bias model may be limited in its ability to account for functional flexibility because it relies too heavily on the equivocal assumption that the left hemisphere is dominant for speech perception as well as speech production; an assumption which similarly limits the utility of numerous other models (e.g., Kimura, (1961a, 1961b, 1967; Inglis, 1965; Treisman, 1969).

On the basis of the previous review of the literature and the findings of this investigation, it is apparent that although numerous insights concerning cerebral hemispheric asymmetries have been gleaned from clinical studies, these have nevertheless led to limited inferences regarding mechanisms of function in the intact brain (Kinsbourne, 1974). Patterns of normal functionally lateralized speech may be maintained as much by between-hemisphere as by within-hemisphere interactions (Kinsbourne, 1974).

Theoretical positions such as this account well for clinical reports on functional deficits incurred from localized brain injury, as well as the factors that may influence recovery of function post-injury; for example, the apparent paradox of

intrahemispheric focal lesions that produce deficits which are not apparent in lobectomy patients. This suggests a role of interhemispheric inhibitory interactions in functional asymmetry (Thatcher, et al., 1983).

Relational and Unitary Processes in Tasks

Bever (1983) has advanced a cognitive theory which may account for the discrepant findings attributable to subject and task factors in DL paradigms involving the presentation of linguistic material to neurologically normal subjects. He has outlined that the dominant neuropsychological theories accounting for hemispheric asymmetries have argued that lateralized function depends on the modality of behavior (Kimura, 1967, 1973; Scheid, Eccles, 1975). Thus, the left hemisphere has been argued to mediate language and sequential reasoning, and the right as specialized for music and visuospatial processing (Kimura, 1967, 1973). More generally, this view has led to the distinction between the left hemisphere as rational, analytic, and sequential, and the right hemisphere as intuitive, holistic, and visuospatial (Bever, 1971; Bryden, 1982; Levy, 1969; Springer and Deutsch, 1981; Walsh, 1978). Subsequent accounts of hemispheric asymmetry have argued that language is mediated by the left hemisphere because it is analytic while visual processing is mediated by the right hemisphere because it is holistic, and so forth (Bever, 1983). Thus, specific modalities (e.g., language vs vision) were argued to be asymmetric, while

asymmetry was argued to be the result of the sort of activity each modality involves. In this manner, considerable confusion has been produced, because circular reasoning has been applied to distinguish analytic and holistic processing. Similar reasoning has been applied in the use of lateralization patterns to differentiate processing styles (Bever, 1983). Dichotomizing perceptual processes as analytic vs holistic does not constitute a theory of functional lateralization; it tells nothing germane to the development, evolution, or biology of functional hemispheric asymmetries, nor does it have much heuristic value (Corballis, 1983). Bever (1975, 1980, 1983) has proposed that this circularity may be avoided by drawing on theoretical cognitive psychology to furnish a technical definition of the two types of activities.

However, cognitive psychological theories have also applied similar circularity in reasoning. A number of cognitive theories have tended to dichotomize hemispheric asymmetry by proposing that the left hemisphere is rational and the right is intuitive, or that the left is propositional and the right is appositional (Bogen, 1969). As well, a number of authors have debated the issue of how to determine whether a mental representation is propositional. The debate has typically gravitated around inferences based on uncertain assumptions: (1) language is generally agreed to be propositional in nature; and (2) language is usually

represented in the left hemisphere; whereas (3) spatially imagery is typically associated with the right rather than the left hemisphere. Consequently, imagery must be essentially nonpropositional in nature (e.g., Kosslyn, and Pomerantz, 1977; Paivio, 1976). However, Pylyshyn (1973, 1978) has argued that the subjective pictorial quality of spatial imagery does not discount the probability that it also is fundamentally propositional in nature.

After a careful analysis of the issue, Anderson (1978) concluded that psychological evidence on cerebral lateralization may do little to resolve the debate of whether a given representation is propositional or not. Even if left-hemisphere processing could be shown to be more analytic, rational, or propositional, than right hemisphere processing, it would tell us little about whether these qualities derive simply from left-hemisphere dominance for language, or whether they are antecedent to it; labels do not substitute for theory (Corballis, 1983).

The issue would appear to be that some authors have used a somewhat more restrictive operational definition of language than others. For example, some authors (e.g., Paivio, 1971, 1976) have described the semantic aspects of language in lexical terms as one manner of accounting for hemispheric asymmetry for speech. While such classifications may provide a convenient way of accounting for the data, they do not necessarily provide an accurate account for the

cortical representation of semiosis. Within the brain, language is not necessarily restricted to lexical representation as we choose to define it. If language is viewed merely as one of possibly numerous complex symbolic systems which function as signs for the organism, it is conceivable that some types of words (e.g., imageable words or emotional words), capable of eliciting meaningful multisensory and/or emotional experiences, may have bi-hemispheric cortical representation, and as such, may be processed as efficiently in the right hemisphere as in the left, because within the brain, language may not function as we define it for daily use, but rather, as a process of cortical excitation with direct correspondence to the process of semiosis. Thus, concrete words may elicit right-hemisphere semantic capabilities because they tend to elicit converging multisensory referents. Similarly, emotional words may elicit right-hemisphere semantic capabilities because they tend to elicit converging emotional referents. In contrast, abstract words may fail to elicit such effects because they tend to elicit divergent, non-sensory, non-emotional referents, which would require fine-grained lexical analysis. By defining the cortical representation of the semantic aspects of language in this fashion, propositional imagery and the role of the right hemisphere in relation to the processing of speech may be accounted for.

Bever's (1983) theory provides a more precise investigative framework than most cognitive theories which have dichotomized hemispheric asymmetry by proposing that the left hemisphere is rational and the right is intuitive, or that the left is propositional and the right is appositional. The basis for Bever's (1983) theory lies in the general consensus that cognitive processing involves the transformation of one form of represented information into another form, and that central processing involves the problem solving mechanisms of the brain, while special purpose processing involves mechanisms that allow us to carry out habitual functions (Anderson, 1980; Chomsky, 1980; Norman, and Rumelhart, 1975; Pylyshyn, 1981; Simon, 1979). The cognitive processes related to hemispheric asymmetries would thus involve, at least in part, semiautonomous "modules" which carry out complex processes (Bever, 1975; Fodor, 1975; Pylyshyn, 1981). Modules may be general purpose or specific purpose (Bever, 1983). Thus, the mechanism for speech would represent one such module. The output of a module would be expressed in units that are relatively accessible. In speech, the output would provide us with a meaning that corresponds to the sound. Whether general purpose or special purpose, each module is postulated to be an information processing system that performs operations on one form of representation that pair it with other forms. Such operations may be internally complex relative to their

input or output. Thus, Bever's (1983) modular concept provides a technical definition that may account for the difference between analytic and holistic processing.

Bever (1983) has also argued that there are essentially two types of cognitive processes: unitary and relational. Unitary processing is argued to access the output or input of a module, whereas relational processing involves the interrelation of more than one output of a module. This distinction may be reflected in the difference between the activities each hemisphere is most adapted to. In terms of this theory, speech is not immovably lateralized in the left hemisphere because the left hemisphere is analytic, but rather, it may be shown that behavioral modalities can shift their laterality pattern if one shifts the sort of cognitive processing that is required of the subject (Bever, 1983). Bever (1983) has also argued that the correctness of this distinction may be tested by demonstrating that the same kind of material is processed preferably on the left or right as a function of the kind of task, not the modality. Thus, if the same kind of stimuli can be processed in different ways, with opposite resulting lateralization patterns, the discrepant patterns may be explained in terms of task demands, individual differences, special training, and so on. However, the patterns could no longer be argued to reflect modality defined type of laterality (i.e., left-hemisphere dominance for linguistic processing because the left

hemisphere is analytic, sequential, propositional, and so on).

Bever's (1983) theory accounts well for the findings reported in the IID experiment. Verbal report may induce the priming of complex information processing systems within the left-hemisphere and produce a greater REA as a function of the task. Manual responders may have shown substantially greater variance in their REA because their task induced a shift in the kind of cognitive processing required. In short, the data from the IID experiment would appear to support Bever's (1983) hypothesis. Language does not appear to be lateralized as a modality defined kind of behavior, since the same kind of material has been shown to be processed preferentially on the left or right as a function of the kind of task required of the subject (i.e., the task demands). Thus, behavioral modalities can apparently shift their laterality pattern if we shift the kind of cognitive processing that is required (Bever, 1983).

There are clinical implications to these findings. With respect to diagnostics, the utility of the DL paradigm may be enhanced by more careful consideration of the type of stimuli employed in the construction of DL tests. By loading the test with CV combinations, and requiring subjects to report verbally, one can be provided with a more valid and reliable measure of left-hemisphere speech processing. This should reduce inter-subject variability considerably while improving

test-retest reliability. Alternatively, subjects could be required to respond manually to different types of stimuli, such as those employed in the IID experiment. This would provide the examiner with an index of right-hemisphere speech capabilities.

The implications for the rehabilitation of diminished linguistic functions in left-hemisphere lesion (e.g., stroke) patients are also apparent. If the right hemisphere is capable of semantic processing, future investigations may clarify methods by which such residual functions may be put to more efficient use. For example, stroke patients presenting with the classic Broca's (1865) aphasia characteristically make numerous semantic paraphasias. This observation may reflect residual right-hemisphere semantic processing functions, but impaired left-hemisphere output functions. Conceivably, if these patients could be shown to rely on multisensory and/or emotional priming, the number of such paraphasias with some types of stimuli (concrete and emotional words) should be reduced considerably, thereby facilitating their communication skills.

Summary

The findings would suggest that in normal right-handed males, the left hemisphere clearly dominates the mediation of speech production and the processing of linguistic information in general, but most specifically verbally mediated language. The right hemisphere, however, apparently

also plays an important mediating function in the semantic processing of some types of linguistic material. Thus, both hemispheres may be considered essential for normal linguistic processing, though perhaps not equally so. The specifics of the linguistic task, such as a verbal mode of response and the use of stimuli that do not elicit emotional and/or multisensory experiences may tend to overshadow the linguistic capability of the right hemisphere. In light of this finding, caution should be exercised in the interpretation of REAs reported from DL paradigms employing verbal report without controlling for stimulus characteristics. These may confound production and perceptual processes. As a result, the ear asymmetry would tend to be largely introduced as a function of task demands; that is, the interaction of verbal output with the type of stimulus used (Haggard & Parkinson, 1971).

Finally, these findings have clinical implications germane to diagnostics and rehabilitation. With regard to diagnostics, future applications of this novel DL paradigm may advance our understanding of differential right-hemisphere semantic processing capabilities in left-handed men and women, as well as left-hemisphere brain damaged patients. Consideration of task demands (i.e., stimulus type interacting with response mode) may allow the construction of more refined DL tests, which should improve the reliability of this instrument by minimizing intersubject variability.

With regard to the rehabilitation of impaired linguistic functions in left-hemisphere brain-damaged patients, the procedure may provide clarification of the extent to which residual right-hemisphere semantic capabilities contribute to semantic paraphasias, and how the teaching of multisensory and/or emotional priming might assist these patients in reducing the occurrence of such paraphasias, thereby facilitating their communication skills.

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Appendix A

STATEMENT OF INTENT

TO BE READ BY AND/OR TO EACH SUBJECT

The goal of this research is to arrive at a better understanding of similarities and differences in how the brains of different people process speech. Your participation in this experiment will provide important information toward this end.

The experiment has three parts. First, you will be given a standard hearing test. This should take about 10 minutes. If your hearing acuity is within the normal range you will be given a dichotic listening test, which requires you to listen to different words coming into both ears at the same time. This should take about 15 minutes. Then, you will be given a second dichotic listening test that is slightly different from the first. This should take about 35 minutes.

At one point during the third phase of the experiment, we will take a short break and you will be asked to complete a personality questionnaire. You will be asked to complete a second personality questionnaire during waiting periods in the experiment. The whole experiment should take about 60 minutes. At each step in the experiment, you will be provided with more specific instructions, but for now, I do not wish to overload you with too many details. When the experiment is over, I will try to the best of my ability, to answer any questions you may have.

Your identity will be known only to the experimenter and your anonymity will be protected by matching your results with an identification number. Only the experimenter will have access to the list that matches the names with the identification numbers. Once the results have been analyzed and this study is completed, the list on which your name matches your identification number will be destroyed.

Should you wish to stop at any time during the experiment, you may do so without justification. No questions will be asked of you, nor will any attempt be made to convince you to continue your participation. You are free to stop whenever you wish to do so. Do you understand? Do you have any questions?

Appendix B

CONSENT FORM

I _____ having freely volunteered my time and participation in this experiment do hereby agree to its conditions. I have been told that the confidentiality of the experimental results will be safeguarded and that my anonymity will be protected by the experimenter. I have read and/or heard the statement of intent and I understand the extent and limits of my participation in this experiment. I have read and/or listened to the above.

Signature of participating subject: _____

Signature of witness: _____

Date: _____

Appendix C

Words differ in their capacity to arouse mental images of things or events. Some words arouse a sensory experience, such as a mental picture or sound, very quickly and easily, whereas others may do so only with difficulty (i.e., after a long delay) or not at all. The purpose of this experiment is to rate a list of words as to the ease or difficulty with which they arouse mental images. Any word which, in your estimation, arouses a mental image (i.e. a mental picture) very quickly and easily should be given a high imagery rating; any word that arouses a mental image with difficulty or not at all should be given a low imagery rating. Think of the words "apple" or "cost". Apple would probably arouse an image relatively easily and would be rated as high imagery; cost would probably do so with difficulty and would be rated as low imagery. Since words tend to make you think of other words as associates, e.g. knife-fork, it is important that you rate only the ease of getting a mental image of an object or an event to the given word.

Your ratings will be made on a seven-point scale, where one is the low imagery end of the scale and seven is the high imagery end of the scale. Make your rating by putting a circle around the number from 1 to 7 that best indicates your judgment of the ease or difficulty with which the word arouses imagery. The words that arouse mental images most readily for you should be given a rating of 7; words that arouse images with the greatest difficulty or not at all should be rated 1; words that are intermediate in ease or difficulty of imagery, of course, should be rated appropriately between the two extremes. Feel free to use the entire range of numbers, from 1 to 7; at the same time, don't be concerned about how often you use a particular number as long as it is your true judgment. Work fairly quickly but do not be careless in your ratings.

Below are four examples. Indicate the ease of getting an image by circling the appropriate number.

	Low Imagery			High Imagery			
MOON	1	2	3	4	5	6	7
ITEM	1	2	3	4	5	6	7
KISS	1	2	3	4	5	6	7
CURB	1	2	3	4	5	6	7

	Low Imagery			High Imagery			
FEAR	1	2	3	4	5	6	7
KILL	1	2	3	4	5	6	7
CHANCE	1	2	3	4	5	6	7
BIRD	1	2	3	4	5	6	7
COST	1	2	3	4	5	6	7
GOAT	1	2	3	4	5	6	7
DEED	1	2	3	4	5	6	7
PAIN	1	2	3	4	5	6	7
CAT	1	2	3	4	5	6	7
FATE	1	2	3	4	5	6	7
ROPE	1	2	3	4	5	6	7
LOVE	1	2	3	4	5	6	7
DEAD	1	2	3	4	5	6	7
HATE	1	2	3	4	5	6	7
FAULT	1	2	3	4	5	6	7
RAGE	1	2	3	4	5	6	7
WEEP	1	2	3	4	5	6	7
GIST	1	2	3	4	5	6	7
HOPE	1	2	3	4	5	6	7
AID	1	2	3	4	5	6	7
SLAP	1	2	3	4	5	6	7
HORSE	1	2	3	4	5	6	7
STAB	1	2	3	4	5	6	7
LAKE	1	2	3	4	5	6	7

	Low Imagery				High Imagery			
MEAT	1	2	3	4	5	6	7	
STYLE	1	2	3	4	5	6	7	
SOUL	1	2	3	4	5	6	7	
SEA	1	2	3	4	5	6	7	
SHIP	1	2	3	4	5	6	7	
RAPE	1	2	3	4	5	6	7	
PRIDE	1	2	3	4	5	6	7	
NUDE	1	2	3	4	5	6	7	
SKY	1	2	3	4	5	6	7	
TREE	1	2	3	4	5	6	7	
TRUTH	1	2	3	4	5	6	7	
WOODS	1	2	3	4	5	6	7	

Appendix D

Words differ in their capacity to arouse an emotion. Some words arouse an emotional experience very quickly and easily, whereas others may do so only with difficulty (i.e., after a long delay) or not at all. The purpose of this experiment is to rate a list of words as to the ease or difficulty with which they arouse an emotional experience. Any word which, in your estimation, arouses an emotion very quickly and easily should be given a high emotion rating; any word that arouses emotion with difficulty or not at all should be given a low emotion rating. Think of the words "agony" and "bronze". Agony would probably arouse an emotion relatively easily and would be rated as high emotion; bronze would probably do so with difficulty and would be rated as low emotion. Since words tend to make you think of other words as associates, e.g. knife-fork, it is important that you rate only the ease of getting an emotional feeling to the given word.

Your ratings will be made on a seven-point scale, where one is the low emotion end of the scale and seven is the high emotion end of the scale. Make your rating by putting a circle around the number from 1 to 7 that best indicates your judgment of the ease or difficulty with which the word arouses emotion. The words that arouse emotion most readily for you should be given a rating of 7; words that arouse emotion with the greatest difficulty or not at all should be rated 1; words that are intermediate in ease or difficulty of emotion, of course, should be rated appropriately between the two extremes. Feel free to use the entire range of numbers, from 1 to 7; at the same time, don't be concerned about how often you use a particular number as long as it is your true judgment. Work fairly quickly but do not be careless in your ratings.

Below are four examples. Indicate the ease of getting an emotion by circling the appropriate number.

	Low Emotion						High Emotion
MOON	1	2	3	4	5	6	7
ITEM	1	2	3	4	5	6	7
KISS	1	2	3	4	5	6	7
CURB	1	2	3	4	5	6	7

	Low Emotion			High Emotion			
FEAR	1	2	3	4	5	6	7
KILL	1	2	3	4	5	6	7
CHANCE	1	2	3	4	5	6	7
BIRD	1	2	3	4	5	6	7
COST	1	2	3	4	5	6	7
GOAT	1	2	3	4	5	6	7
DEED	1	2	3	4	5	6	7
PAIN	1	2	3	4	5	6	7
CAT	1	2	3	4	5	6	7
FATE	1	2	3	4	5	6	7
ROPE	1	2	3	4	5	6	7
LOVE	1	2	3	4	5	6	7
DEAD	1	2	3	4	5	6	7
HATE	1	2	3	4	5	6	7
FAULT	1	2	3	4	5	6	7
RAGE	1	2	3	4	5	6	7
WEEP	1	2	3	4	5	6	7
GIST	1	2	3	4	5	6	7
HOPE	1	2	3	4	5	6	7
AID	1	2	3	4	5	6	7
SLAP	1	2	3	4	5	6	7
HORSE	1	2	3	4	5	6	7
STAB	1	2	3	4	5	6	7
LAKE	1	2	3	4	5	6	7

	Low Emotion			High Emotion			
MEAT	1	2	3	4	5	6	7
STYLE	1	2	3	4	5	6	7
SOUL	1	2	3	4	5	6	7
SEA	1	2	3	4	5	6	7
SHIP	1	2	3	4	5	6	7
RAPE	1	2	3	4	5	6	7
PRIDE	1	2	3	4	5	6	7
NUDE	1	2	3	4	5	6	7
SKY	1	2	3	4	5	6	7
TREE	1	2	3	4	5	6	7
TRUTH	1	2	3	4	5	6	7
WOODS	1	2	3	4	5	6	7

Appendix E

EYSENCK PERSONALITY INVENTORY

FORM A

By H. J. Eysenck
and Sybil B. G. Eysenck

Name _____ Age _____ Sex _____

Grade or Occupation _____ Date _____

School or Firm _____ Marital Status _____

INSTRUCTIONS

Here are some questions regarding the way you behave, feel and act. After each question is a space for answering "Yes," or "No."

Try and decide whether "Yes," or "No" represents your usual way of acting or feeling. Then blacken in the space under the column headed "Yes" or "No."

Work quickly, and don't spend too much time over any question; we want your first reaction, not a long drawn-out thought process. The whole questionnaire shouldn't take more than a few minutes. Be sure not to omit any questions. Now turn the page over and go ahead. Work quickly, and remember to answer every question. There are no right or wrong answers, and this isn't a test of intelligence or ability, but simply a measure of the way you behave.

Section of Answer Column Correctly Marked	
Yes	No
█	⋮
Yes	No
⋮	█

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		E	N	L		
1.	Do you often long for excitement?	Yes	No			
2.	Do you often need understanding friends to cheer you up?	Yes	No			
3.	Are you usually carefree?	Yes	No			
4.	Do you find it very hard to take no for an answer? . . .	Yes	No			
5.	Do you stop and think things over before doing anything?	Yes	No			
6.	If you say you will do something do you always keep your promise, no matter how inconvenient it might be to do so?	Yes	No			
7.	Does your mood often go up and down?	Yes	No			
8.	Do you generally do and say things quickly without stopping to think?	Yes	No			
9.	Do you ever feel "just miserable" for no good reason? . . .	Yes	No			
10.	Would you do almost anything for a dare?	Yes	No			
11.	Do you suddenly feel shy when you want to talk to an attractive stranger?	Yes	No			
12.	Once in a while do you lose your temper and get angry?	Yes	No			
13.	Do you often do things on the spur of the moment? . . .	Yes	No			
14.	Do you often worry about things you should not have done or said?	Yes	No			
15.	Generally do you prefer reading to meeting people? . .	Yes	No			
16.	Are your feelings rather easily hurt?	Yes	No			
17.	Do you like going out a lot?	Yes	No			
18.	Do you occasionally have thoughts and ideas that you would not like other people to know about?	Yes	No			
19.	Are you sometimes bubbling over with energy and sometimes very sluggish?	Yes	No			
20.	Do you prefer to have few but special friends?	Yes	No			
21.	Do you daydream a lot?	Yes	No			
22.	When people shout at you, do you shout back?	Yes	No			
23.	Are you often troubled about feelings of guilt?	Yes	No			
24.	Are all your habits good and desirable ones?	Yes	No			
25.	Can you usually let yourself go and enjoy yourself a lot at a gay party?	Yes	No			
26.	Would you call yourself tense or "highly-strung"? . . .	Yes	No			
27.	Do other people think of you as being very lively? . . .	Yes	No			
28.	After you have done something important, do you often come away feeling you could have done better?	Yes	No			
29.	Are you mostly quiet when you are with other people? . .	Yes	No			
30.	Do you sometimes gossip?	Yes	No			
31.	Do ideas run through your head so that you cannot sleep?	Yes	No			
32.	If there is something you want to know about, would you rather look it up in a book than talk to someone about it?	Yes	No			
33.	Do you get palpitations or thumping in your heart? . . .	Yes	No			
34.	Do you like the kind of work that you need to pay close attention to?	Yes	No			
35.	Do you get attacks of shaking or trembling?	Yes	No			
36.	Would you always declare everything at the customs, even if you knew that you could never be found out? . .	Yes	No			
37.	Do you hate being with a crowd who play jokes on one another?	Yes	No			
38.	Are you an irritable person?	Yes	No			
39.	Do you like doing things in which you have to act quickly?	Yes	No			
40.	Do you worry about awful things that might happen? . .	Yes	No			
41.	Are you slow and unhurried in the way you move? . . .	Yes	No			
42.	Have you ever been late for an appointment or work? . .	Yes	No			
43.	Do you have many nightmares?	Yes	No			
44.	Do you like talking to people so much that you would never miss a chance of talking to a stranger?	Yes	No			
45.	Are you troubled by aches and pains?	Yes	No			
46.	Would you be very unhappy if you could not see lots of people most of the time?	Yes	No			
47.	Would you call yourself a nervous person?	Yes	No			
48.	Of all the people you know are there some whom you definitely do not like?	Yes	No			
49.	Would you say you were fairly self-confident?	Yes	No			
50.	Are you easily hurt when people find fault with you or your work?	Yes	No			
51.	Do you find it hard to really enjoy yourself at a lively party?	Yes	No			
52.	Are you troubled with feelings of inferiority?	Yes	No			
53.	Can you easily get some life into a rather dull party? . .	Yes	No			
54.	Do you sometimes talk about things you know nothing about?	Yes	No			
55.	Do you worry about your health?	Yes	No			
56.	Do you like playing pranks on others?	Yes	No			
57.	Do you suffer from sleeplessness?	Yes	No			

PLEASE CHECK TO SEE THAT YOU HAVE ANSWERED ALL THE QUESTIONS.

Appendix F Subject Number: _____

BALANCED DICHOTIC LISTENING WORD TEST

NAME _____ DATE _____ AGE _____ E: _____

(YELLOW LEAD ON RIGHT EAR)

	<u>LEFT EAR</u>			<u>RIGHT EAR</u>		
01.	port	tea	cow	pack	tent	hat
02.	fur	sale	bee	fame	sum	bond
03.	deck	shoe	gun	duck	ship	gas
04.	vane	zoo	meal	vine	zone	mob
05.	name	plate	trail	nose	pride	track
06.	corn	fleet	sunk	coast	flight	sake
07.	bell	deed	game	bowl	damp	good
08.	sheep	vast	zeal	shine	vent	zest
09.	mill	nail	pace	mass	nine	pin
10.	torn	clock	fresh	tin	cloth	faith
11.	speak	bark	need	spit	belt	night

REVERSE HEADPHONES (YELLOW LEAD ON LEFT EAR)

12.	shell	guard	vote	shore	guest	vault
13.	there	mad	nick	though	map	note
14.	pig	teeth	crust	pal	tongue	cream
15.	fault	sand	brain	flag	send	blown
16.	ditch	glow	shirt	dawn	give	shift
17.	view	this	mouth	vim	then	mink
18.	noon	pork	tan	noun	pan	top
19.	cord	fit	stamp	coop	fog	style
20.	band	noise	glove	birth	neck	grain
21.	shoot	voice	than	shame	verb	that
22.	mine	nice	cord	male	nudge	coop

TOTALS: LEFT EAR _____

RIGHT EAR _____

EAR ADVANTAGE RATIO: (R - L) / (R + L) =

Subject Number: _____

BALANCED DICHOTIC LISTENING WORD TEST

NAME _____ DATE _____ AGE _____ E: _____

(YELLOW LEAD ON LEFT EAR)

	<u>RIGHT EAR</u>			<u>LEFT EAR</u>		
01.	port	tea	cow	pack	tent	hat
02.	fur	sale	bee	fame	sum	bond
03.	deck	shoe	gun	duck	ship	gas
04.	vane	zoo	meal	vine	zone	mob
05.	name	plate	trail	nose	pride	track
06.	corn	fleet	sunk	coast	flight	sake
07.	bell	deed	game	bowl	damp	good
08.	sheep	vast	zeal	shine	vent	zest
09.	mill	nail	pace	mass	nine	pin
10.	torn	clock	fresh	tin	cloth	faith
11.	speak	bark	need	spit	belt	night

REVERSE HEADPHONES (YELLOW LEAD ON RIGHT EAR)

12.	shell	guard	vote	shore	guest	vault
13.	there	mad	nick	though	map	note
14.	pig	teeth	crust	pal	tongue	cream
15.	fault	sand	brain	flag	send	blown
16.	ditch	glow	shirt	dawn	give	shift
17.	view	this	mouth	vim	then	mink
18.	noon	pork	tan	noun	pan	top
19.	cord	fit	stamp	coop	fog	style
20.	band	noise	glove	birth	neck	grain
21.	shoot	voice	than	shame	verb	that
22.	mine	nice	cord	male	nudge	coop

TOTALS: RIGHT EAR _____

LEFT EAR _____

EAR ADVANTAGE RATIO: (R - L) / (R + L) =

Appendix G

DICHOTIC STIMULI FOR PRACTICE CONDITION

WORD	STIM #	MASK
Idea	01	Idak
Sake	03	Sabe
Sale	05	Saig
Sin	07	Siz
Spite	09	Spile
Moral	11	Mardl
Bee	13	Bleg
Cow	15	Cov
Car	17	Cas
Door	21	Dook

Appendix H

Data File: prac Block Set: #1

Block Num# : 4 Date:06-25-1986 RESULTS

Subject I.D.:M.S. 049 Time:15:37:27

Sex:m Age: 27

Handedness:r Response Mode:nv

Stimulus Type# 1					Stimulus Type# 2					Stimulus Type# 3				
Wrd	L(pr-nw)	R(pr-nw)			Wrd	L(pr-nw)	R(pr-nw)			Wrd	L(pr-nw)	R(pr-nw)		
1	0	9	6	1 15 18	13	1	33	39	1 39 45	7	0	9	3	0 15 9
3	0	18	12	0 18 12	15	1	42	45	0 42 39	9	0	18	12	0 18 12
5	0	9	6	1 15 18	17	0	15	12	1 9 12	19	0	6	0	0 6 0
					21	1	33	39	1 39 45					
				0 SCORE 2					3 SCORE 3					0 SCORE 0
				3 TOTAL 3					4 TOTAL 4					3 TOTAL 3
S/T	0.000			0.667	S/T	0.750			0.750	S/T	0.000			0.000
TOT.S/T:	0.333				TOT.S/T:	0.750				TOT.S/T:	0.000			
AVE.ATN:	8.00		16.00		AVE.ATN:	33.75		35.25		AVE.ATN:	5.00		7.00	
S.D.ATN:	3.46		3.46		S.D.ATN:	14.77		15.76		S.D.ATN:	6.24		6.24	
R-L.ATN:	8.000				R-L.ATN:	1.500				R-L.ATN:	2.000			
S.D.DIF:	6.928				S.D.DIF:	5.745				S.D.DIF:	3.464			

Null Category:

	L	R
False Positives:	0	0
Trials:	0	0
Ratio L:	0.000	
Ratio R:	0.000	
ATTN: max	0	min 0
		mean 0

Totals:

Correct:	8
Trials:	20
Ratio:	0.400
Mean ATN L:	17.40
Mean ATN R:	21.00
S.D. ATN L:	16.84
S.D. ATN R:	16.06
R-L DIFF:	3.600
S.D. DIFF:	2.530
t. DIFF:	4.269

Target stimuli presented to the left first

Inter-Stimulus Interval (ISI): 3

Maximum Allowable Response Latency: 1

Data File: ely Block Set: #1

Block Num# : 4 Date:06-25-1986 RESULTS

Subject I.D.:M.S 049 Time:16:13:22

Sex:M Age: 27

Handedness:R Response Mode:NV

Stimulus Type# 1			Stimulus Type# 2			Stimulus Type# 3		
Wrd	L(pr-nw)	R(pr-nw)	Wrd	L(pr-nw)	R(pr-nw)	Wrd	L(pr-nw)	R(pr-nw)
1	1 18 21	0 24 21	25	1 30 33	0 36 33	49	1 39 45	1 39 45
3	1 9 12	0 21 18	27	1 39 45	1 39 45	51	1 39 45	1 39 45
5	0 12 9	1 30 33	29	1 39 45	1 39 45	53	1 36 42	1 30 36
7	0 27 21	0 27 21	31	1 39 45	1 39 45	55	0 12 9	1 6 9
9	0 27 24	1 27 30	33	1 39 42	0 39 36	57	1 27 33	1 27 33
11	1 39 45	1 39 45	35	1 30 36	1 36 42	59	1 27 30	0 27 24
13	0 12 9	1 6 9	37	1 27 33	1 27 33	61	0 15 12	1 15 18
15	0 6 0	0 12 6	39	0 27 24	1 27 30	63	0 12 6	0 6 0
17	0 15 9	0 15 9	41	1 6 12	1 12 18	65	0 18 12	0 24 18
19	0 18 15	1 24 27	43	0 36 33	1 30 33	67	0 6 0	0 12 6
21	0 21 18	1 33 36	45	1 30 36	1 36 42	69	0 24 18	0 18 12
23	0 24 21	1 18 21	47	1 27 33	1 27 33	71	0 6 0	0 12 6

3 SCORE 7		10 SCORE 10		5 SCORE 6				
12 TOTAL 12		12 TOTAL 12		12 TOTAL 12				
S/T	0.250	0.583	S/T	0.833	0.833	S/T	0.417	0.500
TOT.S/T:	0.417		TOT.S/T:	0.833		TOT.S/T:	0.458	
AVE.ATN:	17.00	23.00	AVE.ATN:	34.75	36.25	AVE.ATN:	21.00	21.00
S.D.ATN:	11.25	11.82	S.D.ATN:	9.61	8.04	S.D.ATN:	17.16	15.56
R-L.ATN:	6.000		R-L.ATN:	1.500		R-L.ATN:	0.000	
S.D.DIF:	8.090		S.D.DIF:	3.729		S.D.DIF:	5.117	

Null Category:			Totals:		
	L	R			
False Positives:	0	0	True Negatives:	0	Correct: 41
Trials:	0	0	Trials:	0	Trials: 72
Ratio L:	0.000		Ratio:	0.000	Ratio: 0.569
Ratio R:	0.000				
ATTN: max	0	min	0	mean	0
					Mean ATN L:24.25 R:26.75
					S.D. ATN L:14.86 R:13.69
					R-L DIFF: 2.500
					S.D. DIFF: 2.077
					t. DIFF: 7.122

Target stimuli presented to the left first

Inter-Stimulus Interval (ISI): 3

Maximum Allowable Response Latency: 1

Appendix I

I.D. _____ Age _____

Sex (check one) ___M ___F

SENSORY-MOTOR COORDINATION SURVEY

Check the response that describes you best.

1.) Most people carry their heads with a slight tilt. How do you usually hold your head?

___left ___right ___middle

2.) With which hand do you use an eraser on paper?

___left ___right ___both

3.) Which eye would you use to peep through a keyhole?

___left ___right ___both

4.) With which foot would you kick a ball?

___left ___right ___both

5.) If you had to look into a dark bottle to see how full it was, which eye would you use?

___left ___right ___both

6.) Into which ear would you place the single earphone of a small radio or tape recorder?

___left ___right ___both

7.) With which hand do you remove the top card when dealing?

___left ___right ___both

8.) Which eye would you use to sight down a rifle?

___left ___right ___both

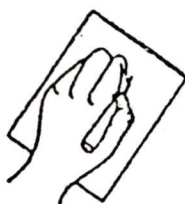
9.) If you had to step up onto a chair, which foot would you place on the chair first?

___left ___right ___both

10.) If you wanted to hear a conversation taking place behind a closed door, which ear would you place against the door?

___left ___right ___both

- 11.) With which hand would you throw a ball to hit a target?
 ____left ____right ____both
- 12.) With which hand do you draw?
 ____left ____right ____both
- 13.) If you wanted to pick up a pebble with you toes, which foot would you use?
 ____left ____right ____both
- 14.) If you wanted to hear someone's heart beat, which ear would you place against their chest?
 ____left ____right ____both
- 15.) Which eye would you use to sight down a telescope?
 ____left ____right ____both
- 16.) Which foot would you use to step on a bug?
 ____left ____right ____both
- 17.) Imagine a small box resting on a table. The box contains a small clock. Which ear would you press against the box to find out if the clock was ticking?
 ____left ____right ____both
- 18.) Consider the four pictures below. Which looks most like the way you hold your hand when writing? (check the box under the correct picture).









Appendix J
Annett Handedness Questionnaire

Age _____

Sex (check one) _____M _____F

CHECK THE RESPONSE THAT DESCRIBES YOU BEST

01. With which hand do you write?
 _____left _____right _____both
02. With which hand do you throw a ball?
 _____left _____right _____both
03. With which hand do you hold scissors when cutting?
 _____left _____right _____both
04. With which hand do you hold a toothbrush?
 _____left _____right _____both
05. With which hand do you hold a match for striking?
 _____left _____right _____both
06. Wich hand is the upper hand when you hold a broom?
 _____left _____right _____both
07. With which hand do you grip a tennis racket?
 _____left _____right _____both
08. With which hand do you hold a hammer when nailing?
 _____left _____right _____both
09. With which hand do you hold the thread when guiding it
 through the needle?
 _____left _____right _____both
10. With which hand do you unscrew a jar lid?
 _____left _____right _____both
11. Which is the upper hand when you hold a shovel?
 _____left _____right _____both
12. With which hand do you remove the top card when dealing?
 _____left _____right _____both
13. With which hand do you hold a comb?
 _____left _____right _____both
14. With which hand do you draw?
 _____left _____right _____both

Appendix K

DICHOTIC STIMULI FOR ABSTRACT CONDITION (1)

Word	Frequency	Log Frequency	Imageability	Emotionality
Aid	130	2.11	2.69	3.18
Chance	131	2.12	2.62	2.98
Cost	229	2.36	1.96	2.42
Deed	8	0.90	2.29	2.15
Fate	33	1.52	1.60	3.27
Fault	22	1.34	1.97	3.70
Gist	1	0.00	1.29	1.64
Hope	178	2.25	2.85	5.33
Pride	42	1.62	2.64	5.12
Soul	47	1.67	2.18	3.22
Style	98	1.99	1.86	3.50
Truth	126	2.10	2.16	4.77

NOTE: The headings are defined as follows:

Word = word to be used in the given condition.

Frequency = actual frequency of the word's appearance in the Corpus of the Kucera & Francis "Computational Analysis of Present Day Modern English".

Imageability = to the imageability ratings for the word, as defined a priori by a cohort group (N=94), according to the methodology of Paivio, Yuille, & Madigan (1968).

Emotionality = emotionality ratings for the word, as defined a priori by a cohort group (N=94), according to the methodology of Paivio, Yuille, & Madigan (1968).

Respective Means and Standard Deviations
for the Above List of Words:

	M	S.D.
Frequency	87.08	72.79
Log Frequency	1.67	0.68
Imageability	2.09	0.48
Emotionality	3.44	1.15

DICHOTIC STIMULI FOR CONCRETE CONDITION (2)

Word	Frequency	Log Frequency	Imageability	Emotionality
Bird	31	1.49	6.54	2.15
Cat	23	1.36	6.57	2.51
Goat	6	0.78	6.68	2.48
Horse	117	2.07	6.65	2.07
Lake	54	1.73	6.59	2.64
Meat	45	1.65	5.72	1.64
Rope	15	1.18	6.27	1.50
Sea	95	1.98	6.51	2.93
Ship	83	1.92	6.67	2.11
Sky	58	1.76	6.39	2.71
Tree	59	1.77	6.70	2.14
Woods	25	1.40	6.33	2.23

NOTE: The headings are defined as follows:

Word = word to be used in the given condition.

Frequency = actual frequency of the word's appearance in the Corpus of the Kucera & Francis "Computational Analysis of Present Day Modern English".

Imageability = to the imageability ratings for the word, as defined a priori by a cohort group (N=94), according to the methodology of Paivio, Yuille, & Madigan (1968).

Emotionality = emotionality ratings for the word, as defined a priori by a cohort group (N=94), according to the methodology of Paivio, Yuille, & Madigan (1968).

Respective Means and Standard Deviations
for the Above List of Words:

	M	S.D.
Frequency	50.92	33.92
Log Frequency	1.59	0.37
Imageability	6.47	0.28
Emotionality	2.26	0.42

DICHOTIC STIMULI FOR EMOTIONAL CONDITION (3)

Word	Frequency	Log Frequency	Imageability	Emotionality
Dead	174	2.24	4.46	6.49
Fear	127	2.10	3.18	6.01
Hate	42	1.62	2.69	6.01
Kill	63	1.80	3.95	5.52
Love	232	2.37	4.10	6.49
Nude	20	1.30	5.87	3.63
Pain	88	1.95	3.72	5.97
Rage	16	1.20	3.69	5.94
Rape	5	0.70	4.14	5.68
Slap	2	0.30	5.48	4.19
Stab	3	0.48	5.15	5.68
Weep	14	1.15	5.12	5.94

NOTE: The headings are defined as follows:

Word = word to be used in the given condition.

Frequency = actual frequency of the word's appearance in the Corpus of the Kucera & Francis "Computational Analysis of Present Day Modern English".

Imageability = to the imageability ratings for the word, as defined a priori by a cohort group (N=94), according to the methodology of Paivio, Yuille, & Madigan (1968).

Emotionality = emotionality ratings for the word, as defined a priori by a cohort group (N=94), according to the methodology of Paivio, Yuille, & Madigan (1968).

Respective Means and Standard Deviations
for the Above List of Words:

	M	S.D.
	-----	-----
Frequency	65.50	75.75
Log Frequency	1.43	0.69
Imageability	4.30	0.95
Emotionality	5.52	0.93

Appendix L

Experimental Stimuli and
Respective Neologisms (Masks).

ABSTRACT		CONCRETE		EMOTIONAL	
Word	Mask	Word	Mask	Word	Mask
Chance	Chogs	Bird	Birk	Fear	Felp
Cost	Covs	Goat	Goab	Kill	Kolp
Deed	Dang	Cat	Cav	Pain	Pake
Fate	Fage	Rope	Roke	Love	Loge
Fault	Faum	Horse	Hork	Dead	Deak
Gist	Jask	Lake	Lang	Hate	Hane
Hope	Hode	Meat	Mowl	Rage	Roke
Aid	Aif	Sea	Sig	Weep	Walp
Style	Styve	Ship	Shug	Slap	Slon
Soul	Soug	Sky	Sko	Stab	Stib
Pride	Prot	Tree	Treg	Rape	Roov
Truth	Trulb	Woods	Walps	Nude	Nole

Appendix M

Blind Examiner's Reaction Times For Responding Fingers and Categories

Trial Number	PURE TONES				WORD TYPE			
	Index Finger	Middle Finger	Ring Finger	Ring Finger	ABSTRACT	CONCRETE	EMOTIONAL	EMOTIONAL
R Hand								
01	.157	.159	.173	.320	.369	.468	.468	
02	.180	.177	.196	.512	.390	.441	.441	
03	.169	.160	.214	.570	.218	.446	.446	
04	.218	.178	.157	.544	.380	.545	.545	
05	.174	.204	.160	.519	.483	.514	.514	
06	.170	.244	.147	.613	.284	.534	.534	
07	.154	.160	.132	.438	.219	.338	.338	
08	.161	.151	.155	.456	.600	.198	.198	
09	.195	.200	.191	.428	.597	.508	.508	
10	.135	.136	.156	.355	.389	.409	.409	
11	.149	.198	.216	.484	.374	.505	.505	
12	.189	.134	.153	.392	.551	.522	.522	
M	.171	.175	.169	.469	.405	.452	.452	
S.D.	.023	.032	.030	.088	.131	.100	.100	

Appendix N

Means and Standard Deviations of Verbal and Manual Responders for Age, Audiometric Test, Lateral Preference, Personality Scales, and Standard Dichotic Listening Test.

	TOTAL (N=60)		VERBAL (n=30)		MANUAL (n=30)	
	M	S.D.	M	S.D.	M	S.D.
AGE	21.87	3.31	21.53	3.12	22.20	3.51
R500HZ	0.50	3.98	0.50	4.02	0.50	4.02
L500HZ	1.33	4.50	1.83	4.25	0.83	4.75
R1000HZ	1.58	3.62	1.33	3.46	1.83	3.82
L1000HZ	1.50	3.94	0.50	3.56	2.50	4.10
R2000HZ	-0.25	4.46	-0.83	4.17	0.33	4.72
L2000HZ	0.42	4.98	1.17	5.03	-0.33	4.90
R4000HZ	1.42	5.97	1.00	5.48	1.83	6.50
L4000HZ	1.67	4.93	1.83	5.00	1.50	4.94
LATPREFC	0.59	0.32	0.55	0.34	0.63	0.29
LATPREFA	0.75	0.16	0.73	0.15	0.77	0.16
EYSENCKL	2.95	2.03	2.80	1.80	3.10	2.25
EYSENCKN	9.48	4.49	9.97	4.17	9.00	4.81
EYSENCKE	12.35	3.80	11.40	3.64	13.30	3.79
RDL	38.38	7.03	39.97	7.77	36.80	5.91
LDL	27.77	5.94	27.77	6.96	27.77	4.83
DLSCORE	16.00	13.40	18.00	15.37	13.91	10.94

Note: R500HZ=dB in right ear at 500 Hz; L500HZ=dB in left ear at 500 Hz; R1000HZ=dB in right ear at 1000 Hz; L1000HZ=dB in left ear at 1000 Hz; R2000HZ=dB in right ear at 2000 Hz; L2000HZ=dB in left ear at 2000 Hz; R4000HZ=dB in right ear at 4000 Hz; L4000HZ=dB in left ear at 4000 Hz; LATPREFC=Lateral Preference Survey of Coren & Porac; LATPREFA=Handedness Questionnaire of Annett; EYSENCKL=Lie scale of Eysenck Personality Inventory; EYSENCKN=Neuroticism scale of Eysenck Personality Inventory; EYSENCKE=Extraversion scale of Eysenck Personality Inventory; RDL=Right-ear words of Dichotic Listening Test; LDL=Left-ear words of Dichotic Listening Test; DLSCORE=Dichotic Listening ratio (R-L/R+L x 100).

Appendix O

Individual Data on Experimental Procedure.

	VERBAL			MANUAL		
	DLSCORE	IID	t IID	DLSCORE	IID	t IID
SS						
1	13.16	1.000	2.703	10.71	1.833	4.456
2	7.69	0.500	2.927	- 1.54	1.167	3.564
3	18.84	3.667	7.962	15.07	- 2.167	-10.147
4	9.43	0.167	0.693	7.94	0.833	6.382
5	8.20	1.333	10.232	13.85	1.667	5.021
6	15.79	0.333	2.261	10.00	- 0.667	- 3.658
7	40.54	1.000	6.902	21.74	0.167	0.631
8	9.86	-0.500	- 3.336	13.89	0.833	5.060
9	30.30	1.000	5.673	30.67	- 2.000	- 8.250
10	11.39	0.833	5.405	7.50	1.000	5.673
11	26.32	-0.667	- 5.491	8.57	- 1.500	- 8.316
12	6.85	1.667	8.749	35.85	0.000	0.000
13	18.68	1.333	9.761	33.33	3.667	9.747
14	42.37	0.500	5.263	8.43	- 1.333	- 6.919
15	40.63	1.500	5.761	29.23	3.667	9.633
16	31.51	-0.333	- 3.658	16.22	3.500	8.746
17	19.51	2.833	9.929	18.52	- 1.833	- 7.582
18	62.86	1.167	7.658	17.46	1.500	6.336
19	10.14	0.333	2.261	26.47	- 2.667	- 7.443
20	29.82	2.000	10.405	27.59	1.333	7.255
21	0.00	2.500	8.958	12.73	1.667	10.294
22	11.11	2.000	6.902	9.80	- 1.833	- 8.980
23	- 9.43	-0.500	- 2.927	18.84	3.167	10.019
24	5.00	0.833	9.979	26.98	2.500	7.122
25	13.79	-1.500	- 4.711	1.49	1.833	6.683
26	6.67	2.000	9.761	- 7.69	0.167	0.387
27	10.77	1.000	6.902	1.89	2.333	8.281
28	6.67	0.167	1.736	0.00	1.167	6.395
29	7.69	2.167	8.144	6.25	3.167	10.374
30	36.84	0.833	5.405	1.64	0.333	1.213
M	18.10	0.972		13.91	0.783	

Appendix P

Summary Accuracy Data.

Block #	VERBAL											
	Abstract			Concrete			Emotional			Total		
	L	R	L+R	L	R	L+R	L	R	L+R	L	R	L+R
1	.322	.358	.340	.669	.772	.721	.317	.386	.351	.436	.506	.471
2	.481	.550	.515	.783	.817	.800	.456	.442	.474	.573	.619	.596
3	.542	.542	.542	.789	.786	.787	.442	.492	.467	.591	.606	.599
4	.567	.597	.582	.750	.781	.765	.475	.506	.490	.597	.628	.612
All 4	.478	.512	.495	.748	.789	.768	.422	.469	.445	.549	.590	.570
MANUAL												
1	.225	.314	.269	.703	.694	.699	.347	.294	.321	.425	.434	.430
2	.339	.444	.392	.722	.786	.754	.419	.358	.389	.494	.530	.512
3	.397	.506	.451	.764	.814	.789	.417	.422	.419	.526	.581	.553
4	.456	.542	.499	.750	.769	.760	.461	.447	.454	.556	.586	.571
All 4	.354	.451	.403	.735	.766	.750	.411	.381	.396	.500	.533	.516
TOTAL												
1	.274	.336	.305	.686	.733	.710	.332	.340	.336	.431	.470	.450
2	.410	.497	.453	.753	.801	.777	.437	.425	.431	.533	.575	.554
3	.469	.524	.497	.776	.800	.788	.429	.457	.443	.558	.594	.576
4	.511	.569	.540	.750	.775	.762	.468	.476	.472	.576	.607	.592
All 4	.416	.482	.449	.741	.777	.759	.417	.425	.421	.525	.561	.543

Appendix Q

FILE: DESCRIPT SPSSX A CMS VM/SP4 - UNIVERSITY OF VICTORIA

TITLE

 THIS FILE CONTAINS THE COMMANDS WHICH
 DESCRIBES PETER ELYS M.A. THESIS DATA
 THIS FILE INCLUDES: (DATA LIST)
 DATA LOCATION
 VARIABLE NAMES
 VARIABLE LABELS
 VALUE LABELS

EACH CASE IN THE DATAFILE CONSISTS OF
 4 RECORDS
 1ST DICHOIC LISTENING DATA
 2ND SUMMARIZED DATA
 3RD PERSONALITY RATINGS ON 16PF
 AND EYSENCK'S 'E' 'I' AND 'L' SCALES
 ACCURACY DATA FOR BLOCKS 3 AND 4 OF IID
 DICHOIC LISTENING TEST
 4TH EMOTIONAL AND IMAGERY RATINGS OF THE
 STIMULUS

THE RESULTS OF THIS DESCRIPTIVE RUN
 ARE SAVED IN THE SPSSX SAVE FILE:

DESCRIPT SPSSXSF

FILE HANDLE DATAIN NAME=MADATA SET 21
 FILE HANDLE DATAOUT NAME=DESCRIPT SPSSXSF

DATA LIST FILE=DATAIN RECORDS=4 HAND R RESPMODE 10 FIRSTEAR J2 SEX 14
 /1 SS 1-3 AGE 5-6 HAND R RESPMODE 10 FIRSTEAR J2 SEX 14
 S000H7 14-20 1500H7 22-24
 R1000H7 26-28 L1000H7 30-32
 S2000H7 34-36 L2000H7 38-40
 S4000H7 42-44 L4000H7 46-48
 R11ACCI 49-50 R1RACCI 51-52
 L1ATPREFC 53-57(3) L1ATPREFA 59-63(3)
 S01 67-64 L01 70-71
 R11ACC2 72-73 R1BACC2 74-75
 R11ACC3 76-77 R1BACC3 78-79

/2 STIMJ 6 STIMP 24 STIMJ 42 STIMP 42 S00IFF3 54-58(3)
 S00IFF1 18-22(3) S00IFF2 36-40(3)
 LAVEATT1 8-11(2) RAVEATT1 13-16(2)
 LAVEATT2 26-29(2) RAVEATT2 31-34(2)
 LAVEATT3 44-47(2) RAVEATT3 49-52(2)
 R1E1PFI0 61-66(3) R21ACCI 68-69 R2RACCI 70-71
 R21ACC2 72-73 R2BACC2 74-75
 R21ACC3 76-77 R2BACC3 78-79

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73 PFA 06-07 PFR 08-09 PFC 10-11 PFE 12-13 PFF 14-15 PFG 16-17
 PFI 18-19 PFL 20-21 PFM 22-23 PFN 24-25 PFQ 26-27 PFO 28-29
 PFRACCI 41-42 PFR02 32-33 PFR34 34-35 PFR04 36-37
 PFRACCI 43-44
 PFRACC2 45-46 PFRACC2 47-48
 PFRACC3 49-50 PFRACC3 51-52
 FYSFNCKL 55-56 FYSFNCKN 58-59 FYSFNCKE 61-62
 R41ACCI 64-65 R41ACCI 66-67
 R4LACC2 68-69 R4LACC2 70-71
 R4LACC3 72-73 R4LACC3 74-75

74	EFFAM	6
	EKILL	7
	ECHANGE	8
	ENTRD	9
	EGOAT	10
	EGFED	11
	EDAIN	12
	ECAT	13
	EFATE	14
	EFOPE	15
	ELOVE	16
	EDEAU	17
	EHAITE	18
	EFAULT	19
	ERAGE	20
	EMFER	21
	ERIST	22
	ERHOPE	23
	ERAPD	24
	ERLAP	25
	ERORSE	26
	ERSTAR	27
	ERLAKC	28
	ERFAT	29
	ERSTYLE	30
	ERSOUL	31
	ERSEA	32
	ERCHIP	33
	ERGRAP	34
	ERRTOR	35
	ERLIQE	36
	ERKY	37
	ERUFF	38
	ERJURH	39
	ERWOODS	40
	ERWOODS	41
	IFEAR	44
	IKILL	45
	ICHANCE	46
	ITRD	47
	ICOST	48
	IGIJI	49

FILE: DESCRPT SPSSX A CMS VM/SP4 - UNIVERSITY OF VICTORIA

IDEED	50
IPAIN	51
ICAT	52
LEAF	53
IPROE	54
ILOVE	55
IDEAU	56
THATE	57
IFAUT	58
IBAGE	59
IMFEE	60
ICIST	61
THOPE	62
TAID	63
ISLAP	64
THORSE	65
ISTAR	66
FLAKE	67
IMFAT	68
ISTYLE	69
ISCOL	70
ISRA	71
ISHIP	72
IRAPE	73
IPRIE	74
INUDE	75
ISKY	76
ITREF	77
ITRUTH	78
IMOODS	79

FORMAT LAIPRFFC LAIPRFFA (F5.3)
 SODIFFE1 SODIFFE2 SODIFFE3 (F4.3)
 LAVEATT1 LAVEATT2
 LAVEATT3 LAVEATT4 (F4.2)
 WIDIFFE1 (F4.3)

VARIABLE LABELS

SS "SUBJECT NUMBER"
 AGE "AGE OF SUBJECT"
 HAND "HANDNESS OF SUBJECT"
 RESPMOOD "SUBJECT'S MOOD OF RESPONSE"
 FIRSTFEAR "SUBJECT'S FIRST FEAR"
 SEX "SEX OF SUBJECT"

REC002 LAIPRFFA RIGHT EAR AT 500HZ
 LEC002 LAIPRFFA LEFT EAR AT 500HZ

FILE: NFDSCRIPT SPSSX A CMS VM/SP4 - UNIVERSITY OF VICTORIA

R1000HZ "AUDIOGRAM RIGHT EAR AT 1000HZ"
 L1000HZ "AUDIOGRAM LEFT EAR AT 1000HZ"
 R2000HZ "AUDIOGRAM RIGHT EAR AT 2000HZ"
 L2000HZ "AUDIOGRAM LEFT EAR AT 2000HZ"
 R4000HZ "AUDIOGRAM RIGHT EAR AT 4000HZ"
 L4000HZ "AUDIOGRAM LEFT EAR AT 4000HZ"
 LATPREFC "LATERAL PREFERENCE: COREN-PORAC"
 LATPREFA "LATERAL PREFERENCE: ANNET"
 R1LACC1 "BLOCK 1 LEFT EAR ACCURACY FOR ABSTRACT"
 R1RACC1 "BLOCK 1 RIGHT EAR ACCURACY FOR ABSTRACT"
 R1L LDI "DICHOTIC LISTENING: RIGHT EAR"
 R1R LDI "DICHOTIC LISTENING: LEFT EAR"
 R1LACC2 "BLOCK 1 LEFT EAR ACCURACY FOR CONCRETE"
 R1RACC2 "BLOCK 1 RIGHT EAR ACCURACY FOR CONCRETE"
 R1LACC3 "BLOCK 1 LEFT EAR ACCURACY FOR EMOTIONAL"
 R1RACC3 "BLOCK 1 RIGHT EAR ACCURACY FOR EMOTIONAL"
 STIM1 "ABSTRACT STIMULUS TYPE"
 STIM2 "CONCRETE STIMULUS TYPE"
 STIM3 "EMOTIONAL STIMULUS TYPE"
 SDDIFF1 "BETWEEN-EAR S.E.DIFF: ABSTRACT STIM."
 SDDIFF2 "BETWEEN-EAR S.E.DIFF: CONCRETE STIM."
 SDDIFF3 "BETWEEN-EAR S.E.DIFF: EMOTIONAL STIM."
 LAVEATT1 "L. EAR AVE: ATTENUATION ABSTRACT STIM."
 RAVEATT1 "R. EAR AVE: ATTENUATION ABSTRACT STIM."
 LAVEATT2 "L. EAR AVE: ATTENUATION CONCRETE STIM."
 RAVEATT2 "R. EAR AVE: ATTENUATION CONCRETE STIM."
 LAVEATT3 "L. EAR AVE: ATTENUATION EMOTIONAL STIM."
 RAVEATT3 "R. EAR AVE: ATTENUATION EMOTIONAL STIM."
 RAVEATT "R. EAR AVE: ATTENUATION COLLAPSED ACROSS STIM TYPES."
 LAVEATT "L. EAR AVE: ATTENUATION COLLAPSED ACROSS STIM TYPES."
 AVEATT1 "AVE: ATTENUATION FOR ABSTRACT STIM. COLLAPSED ACROSS EARS."
 AVEATT2 "AVE: ATTENUATION FOR CONCRETE STIM. COLLAPSED ACROSS EARS."
 AVEATT3 "AVE: ATTENUATION FOR EMOTIONAL STIM. COLLAPSED ACROSS EARS."
 AVEATT "AVE: ATTENUATION OVERALL COLLAPSED ACROSS STIMTYPE AND EARS."
 RLDIFFTO "TOTAL RIGHT-LEFT DIFFERENCE"
 R2LACC1 "BLOCK 2 LEFT EAR ACCURACY FOR ABSTRACT"
 R2RACC1 "BLOCK 2 RIGHT EAR ACCURACY FOR ABSTRACT"
 R2LACC2 "BLOCK 2 LEFT EAR ACCURACY FOR CONCRETE"
 R2RACC2 "BLOCK 2 RIGHT EAR ACCURACY FOR CONCRETE"
 R2LACC3 "BLOCK 2 LEFT EAR ACCURACY FOR EMOTIONAL"
 R2RACC3 "BLOCK 2 RIGHT EAR ACCURACY FOR EMOTIONAL"
 R3LACC1 "BLOCK 3 LEFT EAR ACCURACY FOR ABSTRACT"

FILE: DESCRIPT SPSSX A CMS VM/SP4 - UNIVERSITY OF VICTORIA

R3RACC1	"BLOCK 3 RIGHT EAR ACCURACY FOR ABSTRACT"
R3LACC2	"BLOCK 3 LEFT EAR ACCURACY FOR CONCRETE"
R3RACC2	"BLOCK 3 RIGHT EAR ACCURACY FOR CONCRETE"
R3LACC3	"BLOCK 3 LEFT EAR ACCURACY FOR EMOTIONAL"
R3RACC3	"BLOCK 3 RIGHT EAR ACCURACY FOR EMOTIONAL"
FYSENCK1	"FYSENCK'S LIFE SCALE"
FYSENCKN	"FYSENCK'S NEUROTICISM SCALE"
FYSENCKE	"FYSENCK'S EXTROVERSION SCALE"
R4LACC1	"BLOCK 4 LEFT EAR ACCURACY FOR ABSTRACT"
R4RACC1	"BLOCK 4 RIGHT EAR ACCURACY FOR ABSTRACT"
R4LACC2	"BLOCK 4 LEFT EAR ACCURACY FOR CONCRETE"
R4RACC2	"BLOCK 4 RIGHT EAR ACCURACY FOR CONCRETE"
R4LACC3	"BLOCK 4 LEFT EAR ACCURACY FOR EMOTIONAL"
R4RACC3	"BLOCK 4 RIGHT EAR ACCURACY FOR EMOTIONAL"
RLDIFF1	"RIGHT-LEFT DIFFERENCE FOR ABSTRACT"
RLDIFF2	"RIGHT-LEFT DIFFERENCE FOR CONCRETE"
RLDIFF3	"RIGHT-LEFT DIFFERENCE FOR EMOTIONAL"
R1LACCT0	"BLOCK 1 TOTAL ACCURACY FOR LEFT EAR"
R1RACCT0	"BLOCK 1 TOTAL ACCURACY FOR RIGHT EAR"
R1ACCT0	"BLOCK 1 TOTAL ACCURACY FOR BOTH EARS"
R2LACCT0	"BLOCK 2 TOTAL ACCURACY FOR LEFT EAR"
R2RACCT0	"BLOCK 2 TOTAL ACCURACY FOR RIGHT EAR"
R2ACCT0	"BLOCK 2 TOTAL ACCURACY FOR BOTH EARS"
R3LACCT0	"BLOCK 3 TOTAL ACCURACY FOR LEFT EAR"
R3RACCT0	"BLOCK 3 TOTAL ACCURACY FOR RIGHT EAR"
R3ACCT0	"BLOCK 3 TOTAL ACCURACY FOR BOTH EARS"
R4LACCT0	"BLOCK 4 TOTAL ACCURACY FOR LEFT EAR"
R4RACCT0	"BLOCK 4 TOTAL ACCURACY FOR RIGHT EAR"
R4ACCT0	"BLOCK 4 TOTAL ACCURACY FOR BOTH EARS"
LACCT0T	"LEFT EAR TOTAL ACCURACY (ALL 4 BLOCKS)"
RACCT0T	"RIGHT EAR TOTAL ACCURACY (ALL 4 BLOCKS)"
ACCT0TAL	"TOTAL ACCURACY FOR BOTH EARS AND ALL 4 BLOCKS"
R4ACC1	"BLOCK 4 ACCURACY FOR ABSTRACT"
R4ACC2	"BLOCK 4 ACCURACY FOR CONCRETE"
R4ACC3	"BLOCK 4 ACCURACY FOR EMOTIONAL"
R1LRAT1	"LEFT EAR RATIO FOR ABSTRACT"
R1RRAT1	"RIGHT EAR RATIO FOR ABSTRACT"
R1LRAT2	"LEFT EAR RATIO FOR CONCRETE (BOTH EARS COMBINED)"
R1RRAT2	"RIGHT EAR RATIO FOR CONCRETE"
R1LRAT3	"LEFT EAR RATIO FOR EMOTIONAL"
R1RRAT3	"RIGHT EAR RATIO FOR EMOTIONAL"
R1LRAT4	"LEFT EAR RATIO FOR EMOTIONAL (BOTH EARS COMBINED)"
R1RRAT4	"RIGHT EAR RATIO FOR EMOTIONAL (BOTH EARS COMBINED)"

FILE: DESCRIPT SP55 A CMS VM/SP4 - UNIVERSITY OF VICTORIA

R2LRAT1	"BLOCK 2 LEFT EAR RATIO FOR ABSTRACT"
R2RRAT1	"BLOCK 2 RIGHT EAR RATIO FOR ABSTRACT"
R2CRAT1	"BLOCK 2 RATIO FOR ABSTRACT (BOTH EARS COMBINED)"
R2LRAT2	"BLOCK 2 LEFT EAR RATIO FOR CONCRETE"
R2RRAT2	"BLOCK 2 RIGHT EAR RATIO FOR CONCRETE"
R2CRAT2	"BLOCK 2 RATIO FOR CONCRETE (BOTH EARS COMBINED)"
R2LRAT3	"BLOCK 2 LEFT EAR RATIO FOR EMOTIONAL"
R2RRAT3	"BLOCK 2 RIGHT EAR RATIO FOR EMOTIONAL"
R2CRAT3	"BLOCK 2 RATIO FOR EMOTIONAL (BOTH EARS COMBINED)"
R3LRAT1	"BLOCK 3 LEFT EAR RATIO FOR ABSTRACT"
R3RRAT1	"BLOCK 3 RIGHT EAR RATIO FOR ABSTRACT"
R3CRAT1	"BLOCK 3 RATIO FOR ABSTRACT (BOTH EARS COMBINED)"
R3LRAT2	"BLOCK 3 LEFT EAR RATIO FOR CONCRETE"
R3RRAT2	"BLOCK 3 RIGHT EAR RATIO FOR CONCRETE"
R3CRAT2	"BLOCK 3 RATIO FOR CONCRETE (BOTH EARS COMBINED)"
R3LRAT3	"BLOCK 3 LEFT EAR RATIO FOR EMOTIONAL"
R3RRAT3	"BLOCK 3 RIGHT EAR RATIO FOR EMOTIONAL"
R3CRAT3	"BLOCK 3 RATIO FOR EMOTIONAL (BOTH EARS COMBINED)"
R4LRAT1	"BLOCK 4 LEFT EAR RATIO FOR ABSTRACT"
R4RRAT1	"BLOCK 4 RIGHT EAR RATIO FOR ABSTRACT"
R4CRAT1	"BLOCK 4 RATIO FOR ABSTRACT (BOTH EARS COMBINED)"
R4LRAT2	"BLOCK 4 LEFT EAR RATIO FOR CONCRETE"
R4RRAT2	"BLOCK 4 RIGHT EAR RATIO FOR CONCRETE"
R4CRAT2	"BLOCK 4 RATIO FOR CONCRETE (BOTH EARS COMBINED)"
R4LRAT3	"BLOCK 4 LEFT EAR RATIO FOR EMOTIONAL"
R4RRAT3	"BLOCK 4 RIGHT EAR RATIO FOR EMOTIONAL"
R4CRAT3	"BLOCK 4 RATIO FOR EMOTIONAL (BOTH EARS COMBINED)"
ARLPAT1	"ALL BLOCKS LEFT EAR RATIO FOR ABSTRACT"
ARRPAT1	"ALL BLOCKS RIGHT EAR RATIO FOR ABSTRACT"
ACRPAT1	"ALL BLOCKS RATIO FOR ABSTRACT (BOTH EARS COMBINED)"
ARLPAT2	"ALL BLOCKS LEFT EAR RATIO FOR CONCRETE"
ARRPAT2	"ALL BLOCKS RIGHT EAR RATIO FOR CONCRETE"
ACRPAT2	"ALL BLOCKS RATIO FOR CONCRETE (BOTH EARS COMBINED)"
ARLPAT3	"ALL BLOCKS LEFT EAR RATIO FOR EMOTIONAL"
ARRPAT3	"ALL BLOCKS RIGHT EAR RATIO FOR EMOTIONAL"
ACRPAT3	"ALL BLOCKS RATIO FOR EMOTIONAL (BOTH EARS COMBINED)"
R1LRATIO	"BLOCK 1 LEFT EAR TOTAL RATIO"
R1RRATIO	"BLOCK 1 RIGHT EAR TOTAL RATIO"
R1CRATIO	"BLOCK 1 RATIO FOR BOTH EARS"
R2LRATIO	"BLOCK 2 LEFT EAR TOTAL RATIO"
R2RRATIO	"BLOCK 2 RIGHT EAR TOTAL RATIO"
R2CRATIO	"BLOCK 2 RATIO FOR BOTH EARS"
R3LRATIO	"BLOCK 3 LEFT EAR TOTAL RATIO"
R3RRATIO	"BLOCK 3 RIGHT EAR TOTAL RATIO"
R3CRATIO	"BLOCK 3 RATIO FOR BOTH EARS"
R4LRATIO	"BLOCK 4 LEFT EAR TOTAL RATIO"
R4RRATIO	"BLOCK 4 RIGHT EAR TOTAL RATIO"
R4CRATIO	"BLOCK 4 RATIO FOR BOTH EARS"

FILE: DESCRIPT SPSSX 4 CMS VM/SP4 - UNIVERSITY OF VICTORIA

ARLRATIO	"ALL BLOCKS LEFT EAR TOTAL RATIO"
ARRRATIO	"ALL BLOCKS RIGHT EAR TOTAL RATIO"
BACRATIO	"ALL BLOCKS RATIO FOR BOTH EARS"
RAVEATT	"RIGHT EAR AVERAGE ATTENUATION"
LAVEATT	"LEFT EAR AVERAGE ATTENUATION"
AVEATT1	"AVERAGE ATTENUATION FOR ABSTRACT"
AVEATT2	"AVERAGE ATTENUATION FOR CONCRETE"
AVEATT3	"AVERAGE ATTENUATION FOR EMOTIONAL"
AVEATT	"AVERAGE ATTENUATION (ALL STIMYPES & BOTH EARS)"
DLSCORE	"STANDARD DICHOTIC LISTENING EAR ADVANTAGE RATIO"
EFFEAR	"EMOTIONAL RATING OF FEAR"
EKILL	"EMOTIONAL RATING OF KILL"
ECHANGE	"EMOTIONAL RATING OF CHANGE"
EBIRD	"EMOTIONAL RATING OF BIRD"
ECOST	"EMOTIONAL RATING OF COST"
EGOAT	"EMOTIONAL RATING OF GOAT"
EDEED	"EMOTIONAL RATING OF DEED"
EPAIN	"EMOTIONAL RATING OF PAIN"
ECATE	"EMOTIONAL RATING OF CAT"
EFATE	"EMOTIONAL RATING OF FATE"
EROPE	"EMOTIONAL RATING OF ROPE"
ELOVE	"EMOTIONAL RATING OF LOVE"
EFAU	"EMOTIONAL RATING OF DEAD"
EHATE	"EMOTIONAL RATING OF HATE"
EFAULT	"EMOTIONAL RATING OF FAULT"
EWEST	"EMOTIONAL RATING OF WEST"
EWEST	"EMOTIONAL RATING OF WEST"
FHOPE	"EMOTIONAL RATING OF HOPE"
FAID	"EMOTIONAL RATING OF AID"
ESLAP	"EMOTIONAL RATING OF SLAP"
EHORSE	"EMOTIONAL RATING OF HORSE"
ESTAR	"EMOTIONAL RATING OF STAR"
FLAKE	"EMOTIONAL RATING OF LAKE"
FMEAT	"EMOTIONAL RATING OF MEAT"
GSTYLE	"EMOTIONAL RATING OF STYLE"
ESCAL	"EMOTIONAL RATING OF SEAL"
ESHIP	"EMOTIONAL RATING OF SHIP"
ESNIP	"EMOTIONAL RATING OF SNIP"
EPRIDE	"EMOTIONAL RATING OF PRIDE"
ENUDE	"EMOTIONAL RATING OF NUDE"
ESKY	"EMOTIONAL RATING OF SKY"
ETREE	"EMOTIONAL RATING OF TREE"
ETRUTH	"EMOTIONAL RATING OF TRUTH"
EWOODS	"EMOTIONAL RATING OF WOODS"
IFEAR	"IMAGEACTIVITY RATING OF FEAR"
IKILL	"IMAGEACTIVITY RATING OF KILL"

FILE: DESCRIPT SPSSX A CMS VM/SP4 - UNIVERSITY OF VICTORIA

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ICHANCE "IMAGEABILITY RATING OF CHANCE"
ICOST "IMAGEABILITY RATING OF COST"
IGOAT "IMAGEABILITY RATING OF GOAT"
IDEED "IMAGEABILITY RATING OF DEED"
IPAIN "IMAGEABILITY RATING OF PAIN"
ICAT "IMAGEABILITY RATING OF CAT"
IFATE "IMAGEABILITY RATING OF FATE"
IHOPE "IMAGEABILITY RATING OF HOPE"
ILOVE "IMAGEABILITY RATING OF LOVE"
IDEAD "IMAGEABILITY RATING OF DEAD"
IHATE "IMAGEABILITY RATING OF HATE"
IFAULT "IMAGEABILITY RATING OF FAULT"
IIMAGE "IMAGEABILITY RATING OF IMAGE"
IWEED "IMAGEABILITY RATING OF WEED"
IGIST "IMAGEABILITY RATING OF GIST"
IHOPE "IMAGEABILITY RATING OF HOPE"
ISLAP "IMAGEABILITY RATING OF SLAP"
IHORSE "IMAGEABILITY RATING OF HORSE"
ISTAR "IMAGEABILITY RATING OF STAR"
ILAKE "IMAGEABILITY RATING OF LAKE"
IMEAT "IMAGEABILITY RATING OF MEAT"
ISTYLE "IMAGEABILITY RATING OF STYLE"
ISOUL "IMAGEABILITY RATING OF SOUL"
ISEA "IMAGEABILITY RATING OF SEA"
ISHIP "IMAGEABILITY RATING OF SHIP"
IPIRDE "IMAGEABILITY RATING OF PRIDE"
INUDE "IMAGEABILITY RATING OF NUDE"
ISKY "IMAGEABILITY RATING OF SKY"
ITREE "IMAGEABILITY RATING OF TREE"
IWOODS "IMAGEABILITY RATING OF WOODS"

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VALUE LABELS

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HAND 1 'RIGHT' 2 'LEFT' /
RESPOND 1 'FERRAL' 2 'NONFERRAL' /
FIRSTEAR 1 'RIGHT' 2 'LEFT' /
SEX 1 'MALE'

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LIST VARIABLS=ALL

SAVE OUTFILE=DATAOUT

FILE: MADATA SETL_2 A CMS VM/SP4 - UNIVERSITY OF VICTORIA

001	20	1	2	2	1	00	05	-05	-10	-00	-050104	0720	0600	31	2505080202					
001	1	1000	1600	10549	2	2025	3175	4758	3	1350	1050	8290	1833	020509080301						
001	6	4	3	4	8	4	3	6	2	030508090703	01	17	12	010506080303						
001	67734235171677666475635244455345343	46454636465743553435667644664347534																		
002	24	1	2	1	00	05	05	05	05	050305	0278	0933	32	3310060200						
002	1	2075	2625	5977	2	3350	3250	7160	3	1350	1250	5625	1167	060708100504						
002	1	5105	732	4	7	610	4	5	6	050709060303	01	14	13	041007100405						
002	743141171474464575312316117522263	35174761617521111326727762773456715																		
003	25	1	1	2	1	00	-05	-05	-05	-050105	0944	1000	43	3311090607						
003	1	2400	2800	6928	2	4300	3900	3908	3	2650	2950	7459	1000	040711090608						
003	3	9	6	6	5	5	4	8	0	6	3	9	0709	10080507						
003	463331143317774552545164125437564332	2417262473657632223347764434363252615																		
004	20	1	1	1	1	-05	00	-05	00	00	050102	-0167	1000	35	3009080301					
004	1	2125	2175	4758	2	3425	3675	8660	3	2325	2175	5196	0500	060707090606						
004	6	7	7	6	4	5	6	4	5	7	4	5	080506100706	04	05	14	060808110808			
004	752112713173727723121134114651131	431714247374431341335747742775277737																		
005	23	1	1975	1725	-05	00	05	05	00	-05	100000	0778	0933	42	3109070200					
005	1	7	6	5	8	5	6	7	8	5	7	6	5	5402	-2	167	040309080100			
005	771111714174757747551511371174641161	65171711717431137111777744774357717																		
006	27	1	1	2	1	05	05	05	00	00	00103	0833	0667	41	2804100102					
006	1	1375	1325	9728	2	3175	3725	6502	3	1400	2000	5721	0667	040208110103						
006	1	7	6	5	6	5	3	5	7	4	2	6	040308090307	04	08	15	050509100611			
006	55233252766355252324423335664353	553636236365674762377537737																		
007	21	1	1	1	1	05	00	-05	-05	00	-050502	0222	0533	29	2405100102					
007	1	1400	1200	8613	2	3375	3725	5402	3	550	450	3464	0167	050508100403						
007	6	6	5	7	7	3	6	4	3	6	4	7	8	5	1	6	2	040311100201		
007	664211352417756626555424764763455	34422333424512224241664741272366717																		
008	19	1	2	2	1	05	05	00	-05	05	10	050203	0722	0933	34	2909090201				
008	1	2200	2400	3908	2	4175	4125	4011	3	450	550	5009	0833	060911100102						
008	3	4	7	3	4	7	4	6	7	6	5	4	05	11	060711110001					
008	65171726717366355135575772777657727	22171733717244255455567672775277727																		
009	1	1275	1825	6987	2	2750	2850	7160	3	3125	2975	5792	0889	1000	37	2807080606				
009	9	6	7	7	6	10	6	7	5	6	3	7	010807070907	00	09	16	040707060808			
009	441112511174426645421112237574143	35141115431744446242533534564675455																		
010	21	1	1	1	1	05	00	05	00	00	00001	0667	0667	33	2803060003					
010	1	1450	1550	6179	2	2375	2525	5792	3	2175	2325	5196	1333	020306080706						
010	4	6	5	6	4	9	2	5	5	7	6	4	060409050706	06	05	08	0608060709			
010	6342113634172727272727272727272727	122112115642132	442616236465211211125647731762136617																	
011	19	1	2	1	1	05	05	00	-05	00	050101	0889	0733	33	2711004003					
011	1	1100	1100	6267	2	4150	4250	6179	3	2150	1850	9045	00667	020204090602						
011	4	6	9	7	6	6	7	5	7	5	2	4	05	07	18	030509100605				
011	343222554272323516431572246434456546	45242324626753326145236773774467757																		
012	18	1	1	2	1	00	00	00	00	00	050401	0722	0800	33	2410120205					
012	1	1225	1075	6829	2	4200	4400	2954	3	1025	1075	7868	0333	040411120504						
012	1	6	5	8	7	3	5	4	6	4	8	4	05	12	070507080908					
012	46211151214561742443141122116252131	232311133121242134135713214	23154213																	
013	19	1	1	1	1	05	05	00	-05	00	100204	0889	0800	52	2208020504					
013	1	2400	2400	6267	2	3425	3475	8460	3	2225	2475	5977	1000	050609070406						
013	5	4	5	6	4	5	4	7	7	6	7	5	4	070607080305	03	15	12	070507080908		
013	77413147151777577463615115621774161	35171716725564143142672622672265715																		
014	30	1	2	1	1	00	00	05	00	00	050707	0389	0933	42	2707100202					
014	1	2925	3175	5402	2	3375	3525	8533	3	1825	1475	5977	0167	060908060401						
014	7	6	5	6	6	5	6	0	4	5	7	9	9	3	8	080508090503	05	10	09	040907080604

FILE: MADATA SET1_2 A CMS VM/SP4 - UNIVERSITY OF VICTORIA

014	6752212624	16252551444	1531444	36544343	551626266	166653651	522626522	662346636	6636
016	26	1	1	1	00	00	00	00	00
016	13325	3175	3729	23925	3775	00	6829	31875	2025
016	1777	526	575	577	597	62	0900	090406	04
016	7621	1127	2317	1771	1626	1611	2432	772241	1217
016	25	1	1	1	05	05	00	00	00
017	12525	2575	4011	23050	3350	5427	31675	1625	10379
017	666	67	587	3364	64	4	0407	06090402	06
017	7761	1147	1717	7747	4551	1174	17461	152	1117
018	23	1	1	1	00	05	00	00	00
018	12900	3100	6928	23975	4125	5792	32650	2550	5009
018	264	55	545	88	657	0708	0810	0604	02
018	5512	1421	1433	1431	3332	4212	2324	3322	42
019	22	1	2	2	00	00	00	00	00
019	1650	1550	8023	22725	2975	6987	30850	0950	4306
019	54	82	86	57	57	77	6405	09090302	4
020	7754	7317	3727	7767	1767	3627	7767	7767	7767
020	21	1	2	2	05	10	1001	03	0778
020	1175	1125	5977	23125	2975	4523	32800	2400	5908
020	47	57	84	57	96	77	05	74	0605
020	7741	1147	1517	7577	4525	1411	1311	7731	151
021	1	1	1	1	00	05	00	00	00
021	1200	2000	6439	24425	4475	4758	32575	2525	6987
021	23	56	57	36	17	58	4	63	0707
021	7763	2347	3527	7767	3516	3624	6457	7764	454
022	1	1	2	2	05	00	00	00	00
022	1725	1975	7868	24150	4050	6179	31675	1825	8141
022	47	8	8	7	57	54	93	0307	1090
022	6735	3264	4265	5364	2526	3611	1325	7362	242
023	1	1	1	1	05	00	00	00	00
023	1850	1750	6488	23775	3725	7441	31250	0950	7986
023	57	49	81	610	481	410	716	4	0607
023	5611	1231	3165	5333	3131	2121	1521	1542	151
024	1	1	1	1	05	00	00	00	00
024	2650	2950	6000	23475	3625	5792	32425	2475	00
024	49	65	65	74	62	54	58	0910	0806
024	7634	1326	3417	7766	5364	6265	2253	2663	6472
025	1	1	1	1	00	00	00	00	00
025	12250	2350	5625	23800	4000	6439	30950	1050	3464
025	49	55	33	69	58	37	97	46	9
025	2232	2345	3344	4443	5543	2444	3422	3434	433
026	20	1	1	1	05	05	10	10	10
026	12025	2075	6987	23875	3825	6987	31775	1925	4523
026	797	66	86	45	75	47	0407	1009	0606
026	6731	1171	1516	6637	1536	1511	1311	1666	1151
027	25	1	2	1	00	00	00	00	00
027	12100	2100	7236	23625	3675	7441	31975	1925	7441
027	51	62	38	54	56	47	7	8	7
027	7713	2163	5564	7735	27154	05	00	00	00
028	20	1	2	2	05	00	00	00	00
028	12075	2625	5477	23825	4075	3090	32350	2650	5427
028	57	26	83	24	74	59	3	0709	1010
028	7723	2173	2177	6661	5342	6421	4217	7732	323
029	19	1	2	1	05	00	00	00	00
029	11025	1075	5402	24150	3850	6523	31925	1775	3720

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Ely, P.W., Graves, R.E., & Potter, S.M. (1987, February).

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