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An Introduction to and an Initial Examination of the Visual Half Field Shut Down Theory of Reflective Lateral Eye Movements

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AN INTRODUCTION TO AND AN INITIAL EXAMINATION OF THE VISUAL HALF FIELD SHUT DOWN THEORY OF REFLECTIVE LATERAL EYE MOVEMENTS

by
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This Dissertation submitted by Barbara Arneson Yutrzenka in partial fulfillment of the requirements for the Degree of Doctor of Philosophy from the University of North Dakota is hereby approved by the Faculty Advisory Committee under whom the work has been done.

(Chairperson)

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This Dissertation meets the standards for appearance and conforms to the style and format requirements of the Graduate School of the University of North Dakota, and is hereby approved.

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DEDICATION

To Jerry,
whose love, patience, humor
and hugs have made the past few
years so much easier.

record eye movements, reflective eye movements were observed in two phases. In Phase I, eye movements were recorded while subjects responded to verbal and spatial questions with their eyes open (standard condition) and with their eyes closed. It was predicted that fewer and less extensive eye movements would be made while the subjects responded to questions with their eyes closed because visual distraction was reduced to a minimum. In Phase II, eye movements were recorded while subjects responded to verbal and spatial questions in the standard condition, with the addition of verbal (words) or nonverbal (faces) distractor stimuli presented in their visual field while they responded to the questions. In accordance with the VHF SD theory, it was predicted that more and more extensive eye movements would be made when visual distractor were present than when they were not present. In both phases of this study, more right LEMs were expected to occur to verbal question sets and more left movements were expected to occur to spatial question sets. Furthermore, the nature of the distractor stimuli (verbal, nonverbal) in Phase II was hypothesized to strengthen this differential directional shift when type of distractor was matched with type of question (i.e., verbal question-verbal distractor).

The results demonstrated a complex array of both support and failure to support VHF SD predictions. Significantly more right LEMs were made to verbal than to spatial questions. There was no significant question effect for left LEMs. Significantly more right LEMs were made during distractor conditions than during the standard eyes open condition. Extent measures of right LEMs did not differ during distraction than during the standard condition. There was no difference

to the frequency or extent of left LEMs between these conditions.

In addition to data concerning question and experimental condition effects on LEMs, trials in which no lateral movement occurred were also recorded and accounted for a large proportion of the valid responses in this study. Neither the VHF SD theory nor the EOG methodology utilized effectively addressed the nonlateral trial (NLT) phenomenon. However, consistent with previous reports in the LEM literature, NLT findings revealed that more NLTs occurred to spatial than to verbal questions. Furthermore, consistent with general predictions made by the VHF SD theory, significantly fewer NLTs occurred during distractor conditions than during nondistractor conditions.

Attempts to integrate the results of the present experiment into the VHF SD theory demonstrated the inadequacy of the model, as it now stands, to explain the reflective eye movement phenomenon. Similarly, other LEM explanatory models failed to account for these complex results. The importance of further examination of the effect of visual distraction on the reflective eye movement response was noted. Methodological and theoretical issues for future research are addressed.

CHAPTER I

INTRODUCTION AND REVIEW OF THE LITERATURE

The relationship between brain function and specific behaviors (e.g., thinking, feeling, acting) has been a source of intrigue, speculation, and empirical exploration since antiquity. Evidence that the human brain is comprised of two distinct halves, or hemispheres, was recorded in the scientific-medical literature of the Early Greeks (as reviewed by Clarke & Dewhurst 1972; and Giannitrapani 1967). Attempts to identify and localize function in the cerebral hemispheres generated concepts such as the brain as "seat of the soul," as a place to convert "vital spirits" into "animal spirits," and as a storage place for mental processes. These attempts directed attention exclusively to the internal structures of the brain and ignored what appeared to be a functionless cerebral cortex. By the middle of the 17th century, the validity of ancient concepts of localization of function in the brain received little support and, through the anatomical work of Willis (as cited in Clarke & Dewhurst 1972), attention was directed to the importance of the cerebral cortex in elucidating the relationship between brain function and behavior.

Progress in examining the concept of cortical function was slow and did not receive momentum until the 19th century, at which time numerous, and often opposing, views of cortical localization prevailed. At one extreme were the "localizationists" who espoused that brain function, including intellectual processes, can be precisely localized. Support

for this view ranged from Gall's pseudoscience of phrenology to the empirically based findings of precise representation of speech and motor activity in the cortex as evidenced in the work of Fritsch and Hitzig in 1870 and Broca in 1861. At the other extreme were the "anti-localizationsts," such as Flourens, who, in 1824, opposed attempts to precisely localize functions and proposed, instead, that the brain, though highly differentiated, is equipotential for numerous functions and "acts as a whole."

The controversy between "to localize or not to localize" has continued into the 20th century as new technologies and methodologies have permitted increasing accuracy in examining the notion of cerebral localization of function (Harnad, note 1; Luria 1978; Luria & Simernitskaya 1977). However, the prevailing views about cortical localization have tended to fall between the two extremes described above, and have alternatively proposed that regional specialization or localization of function may co-exist with more global, integrated functions in the brain (Diamond & Beaumont 1974; Hécaen & Albert 1978).

An outgrowth of the research examining localization of cortical function has been investigations into the possibility that various functions may be localized differentially in each of the cerebral hemispheres. Some of the first attempts to identify the sensational, cognitive, and perceptual functions specific to each hemisphere came in the 1860's from pioneering work by Broca and Jackson (as reviewed by Milner 1971). Based on observations of behavioral deficits which follow unilateral brain damage, these investigators proposed that in the human brain, higher cognitive functions may be organized asymmetrically in the left and right hemispheres. More specifically, Broca identified

the left hemisphere as specialized for language; Jackson identified the right hemisphere as specialized for perceptual functions. These early observations of differential hemispheric specialization have served as an impetus for what can now be considered an "information explosion" (Gazzaniga 1970) in laterality research (see reviews by Corballis 1980; Diamond & Beaumont 1974; Levy 1980; and White 1969). New methodologies have permitted elaboration and refinement of Broca's and Jackson's original observations and have generated new explanations and theories to account for the apparent differences between the hemispheres.

For the present study, contributions from three major sources of information about hemispheric specialization will be reviewed: (1) research with brain injured individuals, (2) research with individuals following surgical separation of the cortical commissures ("split brain" patients), and, (3) research with individuals whose brain is intact ("normal"). Particular emphasis will be placed on reviewing the findings of research utilizing neurologically normal individuals and, even more specifically, the research in which the reflective eye movement phenomenon is utilized as a technique to study hemispheric specialization.

Studies of Individuals with Unilateral Brain Damage

As was mentioned in the introduction, the effects of unilateral brain damage on both speech and perception as observed by Broca and Jackson, respectively, in the 1860s, has served as a catalyst for subsequent research in the area of functional hemispheric asymmetry. Since that time, a great deal of information on brain function and hemispheric specialization has accrued from clinical studies of individuals with

lateralized brain damage resulting from trauma, vascular disease, tumors, or surgical interventions (see reviews by Bogen 1969a,b; Hécaen & Albert 1978; and Milner 1971). The prototypic experiment, utilized to examine interhemispheric functional differences with this special population, has been to compare the performance, on a given task, of two groups of individuals: those who have brain damage restricted to the left hemisphere, and those whose brain damage is restricted to the right hemisphere. Performance differences obtained between the two groups have been viewed as a reflection of an underlying difference between hemispheres in executing the particular task studied. That is, when the right hemisphere damaged group performs better than the left damaged group on a verbal task, the inference is made that the left hemisphere has an important role in performing that particular verbal task.

Without reviewing this extensive brain damage literature, several observations about the functional roles of each hemisphere can be summarized. Damage to the left hemisphere, in right handed individuals,[1] has been shown to produce various types of aphasia as well as a general reduction in verbal fluency (Milner 1971); ideational apraxia, or difficulty in demonstrating the use of common objects (Zangwill 1976); and disorders of symbol formulation (Lezak 1976) and abstracting ability (Hécaen & Albert 1978). By contrast, damage to the right hemisphere has been characterized by disorders of spatial orientation (DeRenzi

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[1]All of the material presented in this literature review and in the present study refer to right handed individuals in which the left hemisphere is dominant for language functions. Results of studies examining lateral specialization in left handed individuals are more complex and often inconsistent with the now well-established findings of hemispheric specialization in right handers. For more information on lateralization and left handedness, please refer to Corballis (1980) and Levy (1980).

1978), facial recognition (Benton 1980), musical ability (Bogen 1969a), and appreciation of tonal patterns (Milner 1971). Differences in emotionality between right and left brain damaged individuals have also been reported, such that left damaged individuals respond to stress with catastrophic reactions, while right damaged individuals respond with indifference (see review by Tucker, in press).

The evidence amassed from brain damage studies supporting functional hemispheric asymmetry--though formidable and of value in understanding the relationship between site of damage and certain cognitive functions--has been critized on the basis of both methodological and conceptual limitations of the brain damage paradigm. Methodological limitations have primarily involved difficulties with obtaining groups of unilaterally brain damaged individuals matched for personal variables such as sex, age, premorbid intelligence, and education, as well as, and perhaps more critically, variables such as size and location of the lesion (Bogen 1969a; Madden & Nebes 1980; Ornstein, Johnstone, Herron, & Swencionis 1980). Spurious indications of hemispheric specialization can easily occur if these variables are ignored or unaccounted for in research methodology.

A second focus of criticism of the brain damage studies as they apply to hemispheric specialization has been the limitation that exists in the conceptualization or interpretations arising from the research paradigm. The assumption has generally been made that hemispheric competence for a certain function can be reliably inferred from comparisons of differential performance deficits exhibited by groups of right or left hemisphere damaged individuals executing a task designed to "tap" that function. However, because performing a cognitive task rarely involves

a unitary mental operation/function, Gardner (1978) has criticized this type of interpretation: "The fact that a function is impaired by damage to a specific site does not in itself prove that the function is 'housed there'" (p. 115).

Semmes (1968) also suggests caution in inferences drawn from brain damage studies. In her research with unilaterally brain damaged individuals, Semmes observed that both hemispheres may be proficient for the execution of certain tasks and she further proposed that hemispheric specialization for abilities or functions results instead from dissimilar patterns of neural organization in the hemispheres: abilities appear to be focally represented in the left hemisphere and diffusely represented in the right. Consequently, a lesion to the focally organized hemisphere may produce a more severe deficit on a certain task than is noted if the same lesion is inflicted to the diffusely organized hemisphere. This, in turn, might lead to the possibly incorrect inference that the left, focally organized hemisphere is more important for the task studied. Recent neuroanatomical research has supported Semmes' clinical-behavioral observation in suggesting neurophysiological substrates for hemispheric asymmetries (Gur, Packer, Hungerbuhler, Reivich, Obrist, Amarnek, & Sackeim 1980). However, research attempts to examine possible links between structure and observed functional hemispheric specialization are still in their infancy and have yet to be consistently replicated.

Studies with Commissurotomized, or, "Split Brain," Individuals

The results of studies with unilaterally brain damaged individuals have been more clearly explicated through the use of an ingeneous

technique which purportedly avoids the methodological and conceptual limitations of the former research paradigm. This technique, known as commissurotomy, involves surgical division of the neocortical commissures in order to reduce the frequency and severity of epileptic seizures. In contrast to the unilaterally brain damaged population, the commissurotomized, or "split-brain" individuals possess two relatively normal hemispheres which can theoretically be tested independently of each other, and which, according to Nebes (1974), makes the split brain individuals "ideal subjects for the investigation of lateralization of function" (p. 1).

The bulk of research utilizing commissurotomized individuals to examine the differential roles of the cerebral hemispheres was introduced in the 1960's through the pioneering work of Sperry, Gazzaniga, and Bogen and their associates at the California Institute of Technology. Because literally hundreds of studies have been reported and reviewed in detail elsewhere (Galin 1975, Gazzaniga 1970; Milner 1971; Nebes 1974), no such attempt will be made here. However, several major conclusions about the nature of hemispheric specialization arising from the split brain literature have been made. Utilizing techniques designed to limit sensory input to one hemisphere at a time thereby permitting a comparison of cerebral functions in the isolated hemispheres, these researchers have confirmed the major findings of brain damage studies--left hemisphere specialization for language functions; right hemisphere specialization for visuo-spatial relations. However, they have also reported more specific differences in laterality. For example, the left hemisphere has been shown to be proficient in all language skills and in mathematical calculations (Gazzaniga & Sperry 1967), yet, it has

been shown to have relatively minor involvement in the perception of shapes or patterns (Bogen 1969a). Conversely, these same split brain studies have demonstrated that the right hemisphere is more proficient than the left in copying geometric designs (Bogen 1969a), in tasks involving visualization of spatial relations (Bogen & Gazzaniga 1965; Gazzaniga, Bogen, & Sperry 1965), and in the perception of both complex perceptual material (Milner 1971) and complex configurations which are not readily amenable to verbal labels or descriptors (Levy, Trevarthen, & Sperry 1972). Interestingly, the right hemisphere has been shown to have some limited verbal recognition skills and to understand simple spoken language (Gazzaniga & Sperry 1967; Nebes 1974), but is deficient in syntactic or grammatical understanding (Gazzaniga & Hillyard 1971).

In addition to providing extensive information about how the hemispheres are specialized for what they process, various split brain investigators have provided data suggesting that the hemispheres also differ in their modes of thinking and information processing strategies (Bogen 1969a,b; Galin 1975; Levy 1980; Levy-Agresti & Sperry 1968; Levy et al. 1972; Nebes 1974). For example, Levy-Agresti and Sperry (1968) have reported that when split brain individuals are asked to match 3-dimensional forms (manipulated in either hand) with visually presented 2-dimensional drawings of the forms unfolded, their performance is more accurate when the forms are held in their left hand than when manipulated in their right hand, thus indicating right hemisphere involvement. On the basis of further examination of individual errors, these authors proposed that the two hemispheres utilized different problem solving strategies to complete the task. That is, the left hemisphere analyzed

details of the shapes, while the right hemisphere visualized and synthesized the information. Nebes (1974) has formally characterized these hemispheric differences in mode of functioning by referring to the left hemisphere as "analyzer" and the right hemisphere as "synthesizer." Similar characterizations have been made by Bogen (1969b), Levy (1969), and Zangwill (1976).

Split brain research has broadened examination of hemispheric specialization beyond that of function per se, to include differences in processing strategies between the hemispheres. However, as with the brain damage research, the split brain research paradigm is not without its limitations. Ornstein et al. (1980) have cautioned against making inferences from split brain research about how the hemispheres function in individuals with intact brains because "the disconnection or the epilepsy for which the operation was performed may make brain function in split brain [individuals] quite different from that of normals" (p. 50). This caution has been echoed by Gardner (1978) who has stated that "a description of the commissurotomized [individual] tells us how the human brain--under extreme duress--can be reorganized. What is reveals about the brains of normal individuals is, however, far from clear" (p. 117).

Studies of Individuals with Intact, "Normal," Brains

Research with individuals whose brains have been subjected to either unilateral lesions or commissurotomy has clearly pointed to the specificity of the functions of the two hemispheres. However, because of the aforementioned limitations superimposed on inferences made from these studies, particularly with regard to implications for hemispheric

specialization in the intact brain, researchers have developed various methods of assessing differential specialization of the two sides of the brain in "normal" individuals. The more popular and widely used procedures have included tachistoscopic presentations of visual stimuli (Kimura 1966; White 1969); dichotic listening tasks (Goodglass & Calderon 1977; Kimura 1973); recordings of electroencephalographic, or EEG, activity over both hemispheres (Galin & Ornstein 1972; Gevins, Zeitlin, Doyle, Yingling, Shaeffer, Callaway, & Yeager 1979; Tucker, Ray, & Stern, note 2); and reflective lateral eye movements (Arneson, note 3; Ehrlichman & Weinberger 1978). With the exclusion of the lateral eye movement research, each of these procedures will be briefly reviewed for their overall contributions to further elucidation of hemispheric specialization in the normal brain. For the purposes of this present study, the methods and results of studies utilizing the lateral eye movement procedure will be examined in greater detail.

Tachistoscopic Presentation of Visual Stimuli

The anatomy of the visual system is such that vision to the right of a centrally located fixation point is mediated by the left hemisphere and vision to the left is mediated by the right hemisphere. Thus, utilizing a tachistoscope to make brief presentations of stimulus materials varying in cognitive content (e.g., verbal, nonverbal) to either or both of the visual fields, eye movements are controlled and laterality effects consistent with the major conceptualizations of specialized hemispheric function noted previously have been observed (see reviews by Kimura 1973; and White 1969). For example, a right field superiority has been demonstrated for the perception of Digits (Geffen, Bradshaw, & Wallace, 1971),

alphabetical material (Bryden 1966; Dee & Hannay 1973; Hannay & Malone 1976; Heron 1957; Kimura 1966), and words (Hilliard 1973; Hines 1975, 1978; Klein, Moscovitch, & Vigna 1976; McKeever & Huling 1970, 1971; Mishkin & Forgays 1952). Conversely, left visual field superiority has been shown for the perception of random, unfamiliar shapes (Dee & Hannay 1973; Hines 1975; Kimura 1966); location and quantity of dots (Kimura 1966); and face recognition (Geffen et al. 1971; Hilliard 1973; Hines 1975, 1978; Klein et al. 1976; Leehey, Carey, Diamond, & Cahn 1978; Moscovitch, note 4; Schwartz, note 5).

Even though evidence of tachistoscopic laterality differences has been well documented numerous viewpoints have emerged to explain why these differences should be linked to actual functional hemispheric specialization. At one extreme are those authors who contend that such a link is equivocal and premature at this time in view of the methodological inconsistencies and complications that have characterized this research (Gardner 1978; Jones and Santi 1978; White 1969). More specifically, they cite differences in content and method of presentation of stimuli, response modality, and individual differences between subjects as examples of factors that confound results and interpretations regarding performance differences between visual fields and hemispheric asymmetries.

At the other extreme are authors who contend that in spite of the aforementioned methodological problems, a relationship clearly exists between perceptual laterality and hemispheric specialization. For example, Kimura (1966, 1973) has proposed that right visual field and left visual field advantages in the recognition of certain types of verbal and nonverbal stimuli, respectively, exist because of direct access,

via the structure of the visual pathways, to the left and right hemispheres. That is, according to Kimura, verbal information presented to the right visual field is directly projected to the contralateral hemisphere specialized for verbal functions and, consequently, is more efficiently and rapidly processed than if projected to the left visual field. This "structural" viewpoint has provided post hoc interpretations for research pre-dating its inception (cf. Heron 1957; Mishkin & Forgays 1952). In recent studies, it has been both supported in its original form (see reviews by Kimura 1973; and Madden & Nebes 1980), as well as expanded to incorporate differential visual field effects resulting from not only more efficient reception of verbal and nonverbal materials by the left and right hemispheres, respectively, but also more efficient retention (Hannay & Malone 1976; Moscovitch & Scullion, note 6) and specificity of the cognitive operations used in processing these materials (Dee & Hannay 1973; Hatta 1978; Moscovitch, Scullion, & Christie, note 7).

A second theoretical model that has emerged to explain the relationship between tachistoscopic laterality differences and functional hemispheric specialization has been advanced by Kinsbourne (1970, 1973). Like Kimura, Kinsbourne accepts the fact that the cerebral hemispheres are specialized for certain cognitive tasks. However, unlike Kimura, he suggests that visual field differences are not produced by the directness of anatomical projections to the hemispheres, but, rather, they occur as a result of activation of a given hemisphere effecting an attentional bias to the contralateral visual field. That is, if the left hemisphere is activated with a verbal activity or a verbal set, attention is directed to the contralateral, or the right, side. Correspondingly, a right

hemisphere task or set, such as a visuo-spatial or a musical one, purportedly activates the right hemisphere and directs attention to the left. Primary support for this model has come from studies in which symmetrical performance (i.e., no visual field differences) for the detection of a gap in tachistoscopically presented drawings of squares was altered to favor the right visual field when subjects engaged in concurrent verbal activity. To generalize these findings to other tachistoscopic studies, this basic paradigm has been altered by replacing the drawings of incomplete squares with a variety of verbal and nonverbal stimuli. The results of these modified studies have both supported Kinsbourne's model by demonstrating that a lateralized cognitive set is necessary for the production of lateral differences between visual fields (Bowers & Heilman 1976; Cohen 1975; Hellige 1978), as well as challenged the robustness of his model by showing that tachistoscopic laterality differences can be obtained without lateralized expectancy or set (Berlucchi, Brizzolara, Marzi, Rizzolati, & Umilta 1974; Boles 1979; Gardner & Branski 1976; Kelin et al. 1976).

Any attempt to reconcile the differences between the aforementioned viewpoints is beyond the scope of this review, and, in fact, has yet to be accomplished in the literature. However, research is continually being generated in an effort to examine the nature of the discrepencies and possible commonalities between these views (see, for example, Hines 1978, and, Kimura & Dunford 1974).

Dichotic Listening

Functional asymmetry in the normal, intact brain has been examined via the auditory system through the dichotic listening technique.

Introduced by Kimura in the 1960's, this technique involves channelling different sounds (e.g., words, musical rhythms, nonsense syllables), via headphones, to each of the ears simultaneously. Even though each hemisphere receives the selected input for both ears, Kimura (1961, 1973) has proposed that the neural connections from each ear to the contralateral hemisphere are "stronger" than those to the ipsilateral hemisphere such that when auditory input is presented simultaneously to the ears, it is transmitted "more effectively" to the contralateral than to the ipsilateral hemisphere. Therefore, if verbal functions are localized in the left hemisphere, then verbal stimuli presented to the right ear should, according to Kimura, be more readily recognized and efficiently assimilated. Conversely, a left ear (right hemisphere) superiority should be observed for nonverbal auditory stimuli. This proposed relationship between functional asymmetry and right or left ear superiority in dichotic listening tasks has been supported by numerous studies. For example, right ear superiority has been demonstrated for such verbal materials as digits, words, and consonants (Bartholomeus 1974; Borowy & Goebel 1976; Curry 1967; Kimura 1967, 1973; Sidtis & Bryden 1978; Studdert-Kennedy & Shankweiler 1970). A left ear superiority has been reported for musical patterns and tones (Gates & Bradshaw 1977; Goodglass & Calderon 1977; Gordon 1970; Kimura 1967, 1973; Sidtis & Bryden 1978), nonspeech sounds, such as sneezing, coughing, and laughing (King & Kimura 1972), and nonverbal environmental sounds such as toilet flushing, car starting, and tooth brushing (Curry 1967).

The observations of left ear superiority for verbal stimuli and right ear superiority for nonverbal stimuli, as described above, are consistent with previously reported findings in the clinical, neuropathology

studies, as well as in the tachistoscopic studies with normal individuals. However, as has also been characteristic of previously described results, various interpretations have been proposed to account for the differential ear accuracy in dichotic listening tasks. Perhaps the most influential viewpoint of audition-linked lateralities has been proposed by Kimura (1961, 1967, 1973). She attributes differences in performance between ears in dichotic tasks both to the differences that exist in the structure of the auditory neural system and to the specialized functions of the individual hemispheres. That is, the stronger connections between each ear, and the contralateral hemisphere provide greater efficiency in transmitting auditory input than is available between each ear and the ipsilateral hemisphere. These stronger "crossed" connections interact with increased efficiency in processing or recognizing material whose cognitive content is consistent with the operations for which each hemisphere is specialized. Thus, similar to her viewpoint regarding perceptual lateralities in the visual system, Kimura's interpretation of results from dichotic listening studies are based on relative access to the cerebral hemispheres via neural structures. Her theory has received support in the findings cited above.

An interesting feature of Kimura's conceptualization of dichotic listening effects, as it applies to hemispheric specialization, is the suggestion that when auditory stimuli are presented simultaneously to the ears, the contralateral input inhibits or occludes the ipsilateral input. Her mention of this apparent competition between contralateral and ipsilateral input, resolved through an inhibitory mechanism, is one of the early references in the laterality literature which describes how parts of a specific neural system (i.e., audition) might interact with

each other.

Interaction at the level of the auditory pathways has subsequently been expanded to include speculation about interaction of neural systems at the level of the individual hemispheres. For example, Goodglass and Calderon (1977) presented individuals with spoken and sung digits that were superimposed over three note melodies in a dichotic procedure and observed that the linguistic information yielded a right ear advantage while a left ear advantage was obtained with responses to music. These authors concluded that "each hemisphere can selectively process that component of a complex stimulus for which it is specifically equipped [and] that such, independent, concurrent processing does not appear to be interferred with by the existence of intact communication between hemispheres" (p. 405). Similar findings of complementary, though independent, material-specific information processing between the hemispheres has been reported by Sidtis and Bryden (1978).

Kinsbourne (1970, 1973) has suggested an alternative explanatory model for the perceptual asymmetries observed in the dichotic listening paradigm. Identical to the attentional orientation model proposed to account for visual field performance differences in the tachistoscopic literature, Kinsbourne contends that ear asymmetries reflect an attentional bias to the field contralateral to the activated hemisphere which, in turn, is dominant for the stimulus materials to be attended to. Thus, the left hemisphere becomes activated by verbal material, and attention shifts to the right (ear). Kinsbourne decries the need for assumptions such as "stronger auditory neural connections" to explain dichotic listening effects. However, like Kimura, he speculates interaction between

the hemispheres in producing these effects. More specifically, he suggests that while one hemisphere is activated, the other is inhibited, as is reflected in the direction of the attentional bias. Kinsbourne's viewpoint has received limited examination in the dichotic literature. Support has come primarily from studies in which it has been demonstrated that with identical stimuli, ear advantages are shifted when the subject changes from a verbal to a nonverbal set, or mode of processing (Bartholomeus 1974; Spellacy & Blumstein 1970). In addition, provocative support has come from recent research linking emotional states to hemispheric activation and subsequent attentional bias, in which a right ear advantage for detecting volume of neutral tones presented dichotically, was related to anxiety (Tucker, Antes, Stenslie, & Barnhart 1978) and to depression (Tucker, Stenslie, Roth, & Shearer, in press). Kinsbourne's model has been challenged by studies in which simultaneous opposite perceptual asymmetries (i.e., a right and a left ear advantage) for either different types of stimuli or separate components of the same stimulus have been observed (see, for example, Goodglass & Calderon 1977), and by studies in which ear advantages are present even when an individual has no way of predicting the order of stimulus presentation (no "set), and, thus has no basis for selectively activating a particular hemisphere (as reviewed by Madden & Nebes 1980).

A third, and final, viewpoint that has emerged in the dichotic listening research, and one which seems to serve in a "watchdog" role in nearly all laterality studies, consists of messages of caution regarding interpretations of brain function based on perceptual research with individuals whose brains are intact (Corballis 1980; Gardner 1978; Kershner, Thomae, & Callaway 1977). These authors cite methodological

limitations--such as, individual differences between subjects, problems with specifying the verbal-nonverbal nature of stimuli, methods of responding, and, as compared with the visual system, less clearly differentiated interconnections between the auditory system and the hemispheres--as their primary source of criticism of efforts to interpret hemisphere effects on the basis of differential ear advantages. As with the tachistoscopic research, they contend that interpretations based on possibly erroneous and inconsistent data may lead to spurious conceptualizations about functional hemispheric asymmetry.

Electroencephalographic Recordings

The use of electroencephalographic, or EEG, recordings to explore brain function in neurologically normal individuals has grown with the increasing interest in the study of hemispheric specialization. Viewed by its proponents as a less restrictive and more convenient, nonintrusive procedure than those utilizing lateralized sensory input (i.e., tachistoscope and dichotic listening), EEG recordings have provided valuable information about task related brain activity both within and between the hemispheres (see reviews by Donchin, Kutas, & McCarthy, 1977; and Galin 1974). More specifically, a number of recent studies have demonstrated changes in hemispheric activity level when an individual is engaged in functionally asymmetric (verbal, nonverbal) tasks. For example, Galin and Ornstein (1972), utilizing the EEG technique, observed a relatively higher level of alpha activity (a measure of "idling" or reduced mental effort) over the left hemisphere during spatial tasks than during verbal tasks and, conversely, relatively more alpha activity over the right hemisphere during verbal tasks. In general,

suppression of alpha activity was observed in that hemisphere primarily engaged in a specific cognitive task. This has been confirmed in other frequency-based EEG lateralization studies: there is a decrease in alpha activity in the left hemisphere when individuals are engaged in mental arithmetic (Doyle, Ornstein, & Galin 1974; Morgan, McDonald, & McDonald 1971; Tucker et al., in press); in writing from memory (Galin & Ellis 1975; Galin, Johnstone, & Herron 1978); while listening to verbal-analytic questions (Morgan et al. 1971); and while processing imagery in a linguistic mode (Robbins & McAdam 1974). Conversely, a right hemisphere alpha suppression occurs when individuals perform spatial memory tasks (Morgan et al. 1971), music listening tests (Doyle et al. 1974; McKee, Humphrey, & McAdam 1973), spatial imagery tasks (Morgan et al. 1971; Robbins & McAdam 1974; Tucker et al., in press), and when they synthesize forms (Doyle et al. 1974; Galin & Ellis 1975; Galin et al. 1978; Johnston, Galin, & Herron 1979).

In addition to the results concerning frequency-based EEG studies, as noted above, functional hemispheric specialization has been explored by comparing the asymmetry of averaged evoked potentials. Like the frequency-based studies, the nature of the task performed by an individual is thought to determine the amplitude of the evoked potential over the hemispheres. Unlike the former studies, greater amplitude in a hemisphere indicates greater activity. Thus, larger evoked potential responses to complex visual stimuli are expected to occur over the right hemisphere and larger responses to verbal stimuli should occur over the left hemisphere. These expectations have been separately confirmed by Vella, Butler, and Glass (1972) and Morrell and Salamy (1971), respectively. A more detailed

examination of the evoked potential EEG literature has been presented by Donchin et al. (1977).

Examining differential utilization/specialization of distinct cortical areas under varying stimulus conditions via EEG recordings has generally complemented the data obtained from other brain function studies. However, regardless of the plausibility and promise of the EEG technique as a means of investigating hemispheric lateralization, several inconsistencies have been reported between studies, related primarily to methodological inadequacies and, perhaps, secondarily, to poorly developed theoretical models. Methodological problems have included the following: (1) inadequate experimental designs, (2) failure to validate experimental task variables as addressing lateralized functions, (3) failure to account for individual differences of subjects (i.e., sex, handedness, etc.), and, (4) inadequate measurement and analysis of the data. For a detailed review of methodological considerations in EEG lateralization studies, the reader is once again referred to Donchin et al. (1977).

In addition to methodological problems, inconsistencies between EEG studies have been attributed to a dearth of clearly defined theoretical models which provide coherent _a priori_ predictions regarding the EEG asymmetries observed in normal individuals. One tentative model has been offered by Galin and Ornstein and their associates (Galin 1975; Galin & Ornstein 1972; Ornstein et al. 1980). Based on data obtained from their EEG research, these authors proposed that the differences between hemispheres are primarily related to preference of processing strategy, not simply to the type of stimulus. Thus, the left hemisphere is thought to be specialized for an analytical, logical processing mode

and the right, for a holistic, gestalt mode. Support for this model has come from studies in which EEG alpha intensities shifted from the left to the right hemisphere (1) as difficulty of visuo-spatial task increased (inferring adoption of an analytic strategy; Galin et al. 1978; Ornstein et al. 1980), and (2) as imagery mode changed from spatial to verbal (Robbins & McAdam 1974).

Another dimension of Galin and Ornstein's model is its account of the relationship between the two specialized hemispheres. They propose that a complementary relationship exists between the two hemispheres, characterized by reciprocal inhibition of cognitive systems (when the left hemisphere is activated or engaged, the right hemisphere is inhibited or suppressed) and by "alternation" rather than integration of these systems.[3] This notion of reciprocal inhibition between cognitive systems has been supported by the EEG lateralization studies, as cited above, and has received additional support in EEG studies investigating the relationships between hemispheres with regard to emotionality (see reviews by Shearer, note 8; and Tucker, in press).

While no other theoretical model has been specifically proposed to account for EEG lateralization, previously described models of functional asymmetry in perceptual tasks (cf., Kimura) are applicable in explaining interhemispheric differences in cognitive modes. Furthermore, the interactional aspect of Galin and Ornstein's model is clearly consistent with both Kimura's and Kinsbourne's viewpoints regarding the role of inhibitory mechanisms between neural systems in auditory and visual lateralities.

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[3]This notion is based primarily on Levy's (1969, 1980) idea that separate, specialized functions localized in different hemispheres have developed to reduce conflict between the hemispheres.

Reflective Lateral Eye Movements

An increasingly popular method for investigating cerebral lateralization in neurologically normal individuals has made use of the phenomenon referred to as reflective lateral eye movements (LEMs). This phenomenon, first described bin Teitelbaum (1954), and later named by Day (1964), refers to a shift in direction of gaze that tends to occur when an individual is engaged in reflective thinking. The direction of the gaze shift, or LEM, has been thought to be related to functional hemispheric asymmetry: shifts to the left purportedly indicate involvement of the right hemisphere in the reflective process, and shifts to the right purportedly indicate left hemisphere involvement (Bakan 1969; Kinsbourne 1972). Evidence for this relationship has amassed from primarily two distinct lines of research: studies examining LEMs and personality, physiological, and intellectual characteristics of the individual, and studies focusing on the effects on the direction of eye movements of differing cognitive demand characteristics of reflective questions.

LEMs and individual differences. Numerous studies have sought to explore the relationship between direction of eye movement shift and various characteristics of the individual. Teitelbaum (1954) was the first to report the observation that when a person is engaged in deep mental concentration, his or her eyes move to the right or left more than when not concentrating. This potential link between eye movements and mental activity was re-introduced in the psychological literature and investigated more thoroughly by Day (1964), who found that the direction in which the eyes move is fairly consistent for a given

individual. More specifically, Day noted that when an individual is seated directly across from the questioner, he or she will typically break contact following the presentation of a question requiring reflection and move his or her eyes either to the right or to the left. Duke (1968) offered experimental support for these observations by demonstrating that within a single testing session, the direction of reflective eye movements was a reliable characteristic of the individual. He suggested a new typology, "right mover" and "left mover," to describe individuals differing in their preferred directional shift.

Given that it was possible to classify individuals on the basis of the relatively consisten pattern of their eye movements, subsequent research focused on examining individual differences between right movers and left movers. Day (1964, 1967a,b, 1968, note 9) was the first to propose that direction of eye movements for a given individual has various personality correlates. For example, he (1967a) described left movers as passive individuals who tend to focus attention on internal, subjective experiences, and right movers as more active individuals who tend to focus their attention on more external, objective stimuli.

Bakan (1969) explored these characteristics further by examining their possible relationship with hypnotic susceptibility. He proposed that Day's characterization of the left mover as a subjective, internalized person paralleled descriptions of a "good" hypnotic subject. To test this proposal, he administered the Harvard Group Hypnotic Susceptibility Scale to subjects classified as right or left movers on the basis of the directions of the majority of their LEMs. As predicted,

he found that in contrast to right movers, left movers were more susceptible to hypnosis.

This relationship between personality characteristics, hypnotizeability and characteristic direction of eye movements for an individual has received moderate support. DeWitt and Averill (1976) reported higher hypnotic susceptibility in women who are left movers than in women who are right movers. Gur and Gur (1974) found a positive relationship between left movers and hypnotic susceptibility in a group of male and female subjects, but indicated that when sex of subject was introduced as a moderating variable, that this relationship was present only for male left movers. A non-significant, though positive trend in results suggesting a relationship between hypnotizability and left looking in a mixed sex group of subjects was also reported by Morgan et al. (1971). Finally, though failing to replicate Bakan's (1969) findings of a significant difference between right and left movers on the Harvard Scale, Gur and Reyher (1973) demonstrated that when induction scales are designed to take into account the differential personality styles of the right mover (e.g., active, external focus) or the left mover (e.g., passive, internal focus), the results are consistent with the contention that eye movement directionality and hypnotic susceptibility are related.

In addition to the personality differences between right and left movers, physiological differences have been examined. In a primarily descriptive study, Day (1967b) found that the electroencephalographic (EEG) records of left movers showed greater amplitude and lower frequency in general electrical activity than right movers. Bakan and Svorad (1969) examined the relationship between resting EEG alpha

activity and direction of reflective eye movements and found that left movers produced more alpha activity than right movers. These findings were replicated in Bakan's laboratory (as described in Bakan 1971) in a study demonstrating that left LEMs occur more frequently in individuals with high basal levels of alpha activity. Furthermore, in the Bakan and Svorad study, hypnotizeability scores were obtained for their subjects and were correlated both with amount of alpha production and with eye movement directionality. Results indicated a relationship between these indices such that left movers produced more EEG alpha activity and were more susceptible to hypnosis than were right movers. These findings are consistent with previously described studies implicating a relationship between eye movement directionality and hypnotic susceptibility.

Numerous other differences between right movers and left movers have been studied and have included the following distinctions: (a) individuals who look consistently to the left when asked to respond to a number of reflective questions tend to major in the humanities and classics, while consistent right movers tend to choose majors in the sciences and quantitative/analytic fields (Bakan 1969; Combs, Hoblick, Czarnecki, & Kamler 1977; Gur, Gur, & Marshalek 1975); (b) left movers use more imagery (Bakan 1969; Harnad 1972), are more inner-attentive (Meskin & Singer 1974), and are more artistically diverse and creative than right movers (Harnad 1972; Hines & Martindale 1974); (c) on a task of visual attention (Stroop Color-Word Interference Test) right movers are subject to significantly less interference than left movers (Bakan & Shotland 1969); (d) left movers tend to have slightly higher verbal scores on the Scholastic Aptitude Test (SAT) and right movers tend to

have higher quantitative scores (Bakan 1969; Weiten & Etaugh 1974c); (3) on the Tompkins Polarity Scale, left movers endorse more humanistic items than do right movers (Ashton & Dwyer 1975); (f) left movers tend to be more extreme in their reaction to persuasion in either a pro or con direction, while right movers are associated with more moderate responses (Sherrod 1972); (g) as assessed by the Allport-Vernon-Lindzey Study of Values measure, left movers scored higher on aesthetic and social scales and right movers scored higher on theoretical and economic scales (Weiten & Etaugh 1973); (h) left movers report more psychosomatic symptoms and use ego defenses such as repression and denial, while right movers report more externalized responses to frustration and use ego defenses such as projection and turning against others (Gur & Gur 1975); and, finally, (i) Crouch (1976) reports that left movers and females are relatively more responsive to facial cues, whereas right movers and males are relatively more responsive to verbal cues.

In an attempt to account for the differences between individuals designated as right movers and left movers, Bakan (1969, 1971) has suggested that eye movement directionality is both an indication of relative "predominance" of one of the two cerebral hemispheres and is also related to the functional asymmetry of the brain:

> The relationship between laterality of eye movements . . . and the other variables described above, can be considered in terms of functional asymmetry of the brain. . . . It may be that the left or right movement associated with the reflective process is symptomatic of easier triggering of activities in the hemisphere contralateral to the direction of the eye movement (Bakan 1969, p. 930).

In other words, he has proposed that by simply observing the direction of lateral eye movements during reflection, it may be possible to infer

greater activation (increased cognitive activity and its concommitant increased arousal) in the hemisphere contralateral to the eye movement shift. Furthermore, an individual's tendency to consistently look to the left or right is purportedly related to differential dependence on the right or left hemisphere, respectively, and the cognitive functions they subserve.

To explore Bakan's proposal that individual differences between right movers and left movers are consistent with hemispheric asymmetries, Weiten and Etaugh (1973) examined the differences between right and left movers on a number of tasks specifically related to differential functions of the cerebral hemispheres. As predicted, they found that right movers have greater verbal-analytical skills, as measured by a concept identification task; lesser perceptual-motor skills, as measured by an inverted alphabet task; better quantitative scores on the SAT; and are more likely to major in scientific or quantitative fields in college than left movers. Similarly, Tucker and Suib (1978) compared the performance of right and left movers on tasks designed to tap left and right hemisphere functions (i.e., verbal tests and visuospatial tests, respectively). Like Weiten and Etaugh, these authors reported that categorization as a right mover was associated with higher verbal performance scores and categorization as a left mover was associated with higher visuospatial scores. The importance of these studies was that they supported Bakan's notion that individual differences in LEM patterns are indices of hemisphericity[4] by demonstrating differences between left and right movers on variables clearly related to specialized cognitive functions of the

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[4]The relative importance of the left or right hemisphere in a person's functioning has been referred to as "hemisphercitity" (Bogen 1969a,b).

hemispheres.

While the bulk of the eye movement research described thus far has fairly consistently supported both Day's and Bakan's observations, there have been a number of studies which have reported results inconsistent with these authors' findings. For example, Etaugh (1972) investigated the relationship between LEMs and personality characteristics. She reported significant correlations between eye movement directionality and a number of personality characteristics (as measured by the Sixteen Personality Factor Test), but not in the manner expected by the earlier research of Day or Bakan. Etaugh found that unlike the less assertive, inner focused left movers described by Day (1967a), the left movers in her study were less affected by feelings, less suspicious, more assertive, and less shrewd than the right movers. An attempt to cross validate these findings on another sample of subjects, using the same personality test, failed to replicate her previous results and demonstrated instead a non-significant relationship between personality characteristics and LEM direction (Etaugh & Rose 1973). Similar failures to demonstrate consistent personality differences between right and left movers have been found in studies utilizing other standard personality tests, such as the Rorschach Inkblot Test (Barnat, note 10) and the Minnesota Multiphasic Personality Test (Hartlage & Tollison 1979), and on measures of field dependence-independence (Ehrlichman 1977; Hoffman & Kagan 1977). However, as both Etaugh (1972) and Ehrlichman and Weinberger (1978) have asserted, the inability of these studies to fairly consistently replicate relationships between LEMs and personality variables may be at least partially related to the low reliability of personality tests in general,

or to the selection of personality tests that are inappropriate for assessing personality differences that may be associated with LEM patterns.

In addition to the conflicting evidence concerning consistent personality correlates of right and left movers, further evidence challenging Day's and Bakan's observations regarding cognitive correlates and eye movement tendencies has been reported. Galin and Ornstein (1974), for example, found no difference in preference/consistency of eye movement direction between a group of individuals with high spatial abilities and a group of individuals with high verbal abilities. Ehrlichman (1977) and Hiscock (1977b) reported no differences between right and left movers on a variety of verbal (e.g., vocabulary, verbal imagery) and spatial (e.g., spatial relations, embedded figures) tasks. Taken together, these studies stand in opposition to the concept of eye movement tendency as an index of individual differences in cerebral function, and, as Ehrlichman and Weinberger (1978) have contended, weaken the assumption that LEM patterns reflect hemisphericity.

Several explanations for the discrepancies between studies examining the relationship between eye movement directionality and characteristics of the individual have been offered. One explanation mentioned previously involves the low reliability of personality measures used to examine personality correlates (cf. Etaugh 1972). A second explanation is related to the reliability of the LEM phenomenon itself. Though direction of LEMs within a given session has been shown to be highly consistent for many individuals (Bakan 1971; Ehrlichman and Weinberger 1978; Etaugh & Rose 1973; Weiten & Etaugh 1973), test-retest scores have been somewhat less highly correlated. For example, Templer,

Goldstein and Penick (1972) found a lack of stability of eye movement direction for an individual across time (r = .35). Etaugh and Rose (1973) reported a moderate reliability (r = .55) when the subjects were asked the same questions in two sessions and a somewhat higher reliability (r = .77) when two different, though equivalent, forms of questions were asked. Moderate test-retest reliability was also found in studies by Tucker and Suib (1978) and Crouch (1976), both reporting reliabilities of r = .65. The highest test-retest reliabilities were reported by Bakan and Strayer (r = .78, 1973) and Hoffman and Kagan (r = .89 for males, r = .90 for females; 1977). These data when viewed together, suggest that LEMs are relatively reliable, though the variability in between session reliability reported in these studies generates doubts concerning the relationships which might exist between the LEM phenomenon and stable characteristics of the individual.

A final explanation that has been offered to account for discrepancies in the LEM studies of individual differences is methodological inconsistencies. Hiscock (1977b) cited methodological differences and sampling of subjects as possible sources for the differences between his observations and those of other authors. Templer et al. (1972) questioned the reliability of the judgement of eye movement observers within and between the different LEM studies and recommended that future research be carried out under well specified and standardized conditions. Somewhat related to this latter point is the lack of attention given in these studies to the type of questions utilized to elicit the LEM response (Barnat, note 10). Barnat contended that if lateralization and characteristics of the individual (à la Bakan 1969) are going to be adequately examined, then the cognitive content of the questions

needs to be considered.

In summary, researchers have reported that when people are asked a question requiring reflection, they frequently look briefly to one side or the other before answering. The direction of this eye movement has been found to be a moderately reliable individual characteristic and has been correlated with a variety of personality, physiological, and cognitive measures. For example, individuals who consistently look to the left tend to produce more EEG alpha activity, are more hypnotizeable, have lower SAT quantitative scores, use more imagery, and tend to focus on internal, subjective experiences than individuals who consistently look to the right. Bakan (1969, 1971) has proposed that the differences between left and right movers reflect their differential dependence on the right and left cerebral hemispheres, respectively, and, more specifically, that LEMs are related to functional hemispheric asymmetries. The robustness and generalizeability of the reported individual differences between right and left movers have been challenged primarily on the grounds of methodological inconsistences and inadequacies.

LEMs and question type. Bakan's (1969, 1971) speculation that eye movement directionality is an indication of cerebral hemispheric activation contralateral to the direction of the eye movement has provided a basis for the investigation of perhaps one of the most important variables influencing the eye movement phenomen--the type of reflective question used to elicit the movement. That is, since the cognitive activity in which a person is engaged may differentially influence direction of eye movements (as suggested by Bakan), and, since certain questions differ in cognitive demands (and, thus, in their ability to

differentially engage the hemispheres), it has become essential to examine the relationship between direction of eye movement and type of question.

The effect of kind of reflective question used to evoke LEMs has not been adequately investigated in any of the studies mentioned in the section above, though the possible importance of its effect was alluded to by Barnat (note 10). A number of recent studies have focused on this effect and have provided support for the existence of a relationship between eye movement directionality and the processing of differing kinds of questions. Kocel, Galin, Ornstein, and Merrin (1972) "suspected" that the type of question might be an important variable in view of evidence indicating differential specialization of the cerebral hemispheres for differing cognitive functions (as described in preceding sections of this paper). To test this "suspicion" they designed 20 questions that were expected to engage primarily the left hemisphere (verbal, mathematical) and 20 questions expected to activate primarily the right hemisphere (spatial, musical). These questions were then presented in blocks (to enhance their cognitive demand characteristics) to each subject individually via an intercom system. Eye movement responses were recorded on videotape equipment and the first eye movement following each question was judged for its lateral (right, left) component. Kocel et al. found that while both types of questions were equally effective in evoking lateral eye movements, subjects made a significantly higher percentage of right LEMs in response to the "left hemisphere" questions than in response to the "right hemisphere" questions, indicating a significant effect of the cognitive demand characteristics of their questions on eye movement directionality.

These authors also evaluated the distribution of direction of eye movements for each subject across combined sets of questions to test the hypotheses that individuals tend to shift predominantly either to the right or left, and, additionally, confirmed the findings of researchers examining individual differences and LEMs (cf., Day 1964; Bakan 1969) that eye movement directionality is a reliable characteristic for at least some individuals. However, they noted that an individual's tendency to move his or her eyes in one direction is strongly modified by the cognitive demands of the questions.

In accordance with Kocel et al. (1972), Kinsbourne (1972) confirmed a relationship between the processing of different types of reflective questions and the direction of lateral eye movement. He presented to each of 20 right handed subjects three sets of questions: 20 spatial (requiring subjects to visualize and specify spatial relationships of familiar local landmarks and visual arrangements), 20 verbal (interpretation of proverbs), and 20 numerical (simple calculations and problems based on the quantitative ability sections of the Medical College Admissions Test Study Book and the Graduate Record Examination Study Book). The experimenter sat directly behind the subject while asking the reflective questions. Eye movements were recorded by videotape and the first gaze shift and the first head movement after completion of each question were judged for direction (up, down, right, left). Kinsbourne reported that horizontal eye and head movements were generally to the right during the verbal questions, to the left during the spatial questions, and showed no differences during the numerical problems. To explain these findings, he proposed that eye movements occur as a result of activation of cognitive

functioning of one hemisphere "overflowing" into the orientation system of the same hemisphere, which in turn causes eye movements to shift toward the space contralateral to that hemisphere.[5] Thus, because the left hemisphere is specialized for verbal materials, when a person reflects on a verbal question, gaze will be directed to the right. An analagous interaction occurs between right hemisphere processing and leftward attentional shifts. Furthermore, Kinsbourne proposed that vertical directional shifts reflect simultaneous, or bilateral, activation of the hemispheres, but seemingly minimized this dimension of his model. Kinsbourne's model, hereafter referred to as the "Ocular-Motor Synkinesia (OMS)" model, provided both an elaboration of Bakan's (1969) hypotheses relating eye movement directionality to "easier triggering," or greater activation, in the hemisphere contralateral to the eye movement, as well as a neurophysiologically based explanation of eye movement directionality and hemispheric asymmetries.

Weiten and Etaugh (1974a) offered additional support for the hypothesis that the cognitive demands of reflective questions influence LEM directionality. In their study, subjects were presented four sets of 12 questions each: verbal (interpretation of proverbs, spelling, definition of words); numerical (moderately difficult arithmetic problems selected from the Numerical Ability Subtest of the Differential Aptitude Tests), spatial (requiring visualization of spatial relations), and musical (familiar piano melodies which the subject was asked to identify). All questions were administered by an experimenter seated

[5]This model is similar to the attentional bias models Kinsbourne proposed to explain visual field and auditory lateralities. He contends that his attentional model is equally applicable as an explanatory tool for reflective eye movement research (Kinsbourne 1973).

directly across from the subject. Musical items were administered via tape recordings. The question sets were presented in homogeneous sets to half the subjects and in mixed sets to the other half of the subjects, to test the hypothesis that homogeneous presentation would emphasize demand characteristics of the questions, and, therefore, elicit more eye movements in the expected direction. The subject's first eye movement following completion of the question were recorded by a video camera situated directly behind the experimenter. Eye movements were scored as either right, left, none (e.g., no change in gaze before answering the question), or invalid (e.g., no eye contact with experimenter at the end of the question or if there were any doubts about direction of gaze shift). Analyses of the data indicated that, as predicted, verbal and numerical questions elicited a greater proportion of LEMs to the right than did the spatial or musical questions, with the largest discrepancy occurring between numerical and musical questions. Furthermore, they reported that question sequence (homogeneous versus mixed) had no significant effect on the proportion of right movements observed for each of the four types of questions.

In a follow-up study, Weiten and Etaugh (1974b) attempted to replicate their findings regarding the differential effect of numerical and musical questions on eye movement directionality. Subjects were presented with homogeneous sets of 15 mathematical and 15 musical questions by an experimenter (and tape recorder) seated directly behind them. Eye movement recording and scoring procedures were identical to those used in their previous study. On the trials where valid LEMs were observed, a significantly greater proportion of movements were made to the right on mathematical questions than on musical questions.

This finding was consistent with the results of their earlier study.

Combs et al. (1977) examined the effects of question type on the direction and frequency of LEMs in college students majoring in language related fields, visual arts, or "mixed" fields (i.e., not specifically emphasizing skills in visual or language expression). Utilizing a procedure similar to Weiten and Etaugh (1974a), the experimenter sat directly in front of the subject and administered ten verbal and ten non-verbal (spatial, musical) questions, in a mixed set format. Eye movements were recorded by a video camera located behind the experimenter. Unlike previous studies reviewed thus far, these experimenters scored lateral direction of initial eye movements following the start of each question (rather than at completion of question), and tallied total number of LEMs from start of question to the end of the subject's answer. Results indicated that the cognitive demands of the questions (verbal or non-verbal) significantly influenced the direction of both initial and total number of eye movements only in the group of "mixed" majors. For this group, significantly more right movements were made to verbal than to non-verbal questions. Combs et al. attributed the unexpected nonsignificant results for the more "specialized" majors to a specific cognitive style in approaching the questions that may be somewhat resistent to the different cognitive demands (in line with Bakan's (1969) thinking).

Whereas the aforementioned studies have focused primarily on the effect of cognitive characteristics of the reflective questions used to elicit LEMs, a few researchers have investigated the effects of varying the affective tone of questions. For example, based on research implicating the right hemisphere in the regulation of affect,

Schwartz, Davidson, and Maer (1975) predicted that the emotional content of a question would also affect the directional shifts in eye movements and that this "affective quality" would be distinguishable from the more cognitive (verbal versus spatial) demand characteristics of the questions. Two experiments were performed involving a total of 24 right handed subjects. Each subject was administered 40 questions composed of equal number of verbal-nonemotional, verbal-emotional, spatial-nonemotional, and spatial-emotional questions, which were presented in a counterbalanced order. In both experiments, questions were presented and eye movements scored by an experimenter seated directly in front of the subject. The direction of the first LEM following each question was recorded (blinks and stares were scored as "no response). Data from both studies were combined because of a similar pattern of results in each and indicated that, as predicted, (1) verbal questions elicited more right LEMs than spatial questions, and spatial questions elicited more "no responses" than verbal questions, regardless of emotional content; (2) emotional questions resulted in more left movements that comparable non-emotional questions, regardless of cognitive content; and, (3) the interaction between emotional content and cognitive demands of questions showed that emotional-spatial questions elicited the greatest number of left movements and that non-emotional-verbal questions elicited the greatest number of right movements. These authors concluded that their results support the hypothesis that LEMs are differentially influenced by cognitive demands of questions and "that affective processes can be differentiated from cognitive processes in terms of hemispheric processing" (p. 288).

Tucker, Roth, Arneson, and Buckingham (1977) attempted to replicate and extend the findings of Schwartz et al., by varying not only the affective tone of questions, but also the affective tone of the experimental situation. That is, given the findings of Schwartz et al. of more left movements (greater right hemisphere activation) to emotional questions than to non-emotional questions, these authors were interested in examining the effects of psychological stress on eye movement directionality in response to differing types of questions. The 40 questions used by Schwartz et al. were divided in half such that five of each category comprised a 20 question set. One of these question sets was then presented to the subject under a "neutral" condition and the other set was presented to the same subject under a "stressful" condition. Both lateral and nonlateral eye movements were recorded by an experimenter seated in front of the subject. Analyses of the data indicated significantly more left eye movements to emotional than to non-emotional questions (thus replicating part of the Schwartz et al. study). The number of left movements increased significantly during the stress condition regardless of question content, signifying to these authors that emotional arousal produces greater right than left hemisphere activation. The effect of cognitive content of question (verbal, spatial) on LEMs was not reported.

The role of emotion and cognition in eye movement directionality was examined even more specifically in a study by Ahern and Schwartz (1979). Similar to the studies described above, these authors observed LEMs made in response to a series of questions designed to manipulate both the verbal and spatial requirements, as well as the affective tone. However, unlike previous researchers, the type of affective tone was

more specifically delineated in the reflective question such that the questions were characterized as representing positive (happiness, excitement), negative (sadness, fear), or neutral emotions. Sixty questions were developed (six of each combination of verbal plus emotional tone and spatial plus emotional tone) and were administered to each subject via an intercom. The first lateral eye movement following each question was recorded by a video camera. Results indicated a non-significant effect of verbal-spatial question categorization on direction of eye movement, and a significant effect of emotional tone on LEM. More specifically, these authors reported significantly more right eye movements to positive emotion questions than to questions involving fear, regardless of cognitive content. To account for these results, Ahern and Schwartz suggested that the relationship between positive and negative emotions and LEMs may be more robust than the relationship between LEMs and cognitive mode manipulations, but acknowledged that methodological differences between their study and those of other researchers might be a major contributing factor to the discrepancies in the reported results.

The majority of the studies described thus far have focused primarily on the effect of different kinds of questions on the horizontal/lateral direction of eye movements. Some of the researchers (cf., Schwartz et al. 1975; Weiten & Etaugh 1974a) scored stares and blinks in a separate, nonlateral eye movement category, but relegated only minor importance to their presence in LEM results. The vertical (up, down) dimensions of eye movements also tended to be ignored seemingly on the assumption that they, like stares, have little or no significance for reflecting hemispheric activation. However, in noting that spatial questions consistently elicit more up movements than verbal questions,

Kinsbourne (1972) introduced the possibility that both lateral and nonlateral aspects of eye movements may be important indications of the mode of information processing utilized by a person when engaged in reflective thinking.

In order to further examine both lateral and nonlateral dimensions of eye movements, Galin and Ornstein (1974) studied eye movement directionality in subjects whose vocations emphasized either verbal-analytic (lawyers) or spatial-holistic (ceramicists) cognitive modes. Subjects were presented with three sets of 20 questions each: a verbal set (semantic, logic, math), a spatial set (visualization of complex forms), and a "neutral" set (designed to be amenable to either verbal or spatial processing). Questions were presented via an intercom and eye movements were recorded on videotape and later judged for both lateral (right, left) and nonlateral (up, down, stare) components. Regarding the effect of question type on eye movement directionality, the results indicated the presence of significantly more down movements on verbal questions as compared to spatial questions and significantly more stares on spatial questions as compared to verbal questions. Also, while the observed differences were in the direction predicted (i.e., more right movements on verbal questions), significant differences between question types with regard to the horizontal dimension of eye movements were not found. The authors attributed this latter finding to both the extreme cognitive specialization of the subject sample as well as the possibility of overly demanding or nonhomogeneous question sets. Consequently, a second study was undertaken in which a modified question set consisting of 20 verbal questions (definitions, proverbs, phonemic items) and 20 spatial questions (less complicated spatial orientation tasks) was

administered to a non-specialized group of subjects. Following the same procedure of recording eye movements as used in their first study, the investigators noted a significant effect of question type on eye movements in both the lateral and nonlateral directions such that verbal questions elicited more down and right movements as well as fewer stares than did spatial questions. Galin and Ornstein concluded that both lateral and nonlateral components are important indicators of differential cognitive involvement even though interpretations of vertical movements and stares are not as clear as interpretations of horizontal movements. Furthermore, they asserted that both components should be included in studies utilizing reflective eye movements as indications of hemispheric functioning.

Ehrlichman, Weiner, and Baker (1974) performed a series of experiments in which they attempted to replicate and extend the findings for both lateral and nonlateral eye movement shifts in response to questions designed to elicit differential hemispheric activation. In the process of doing this, they also introduced a new variable into the reflective eye movement research--the effect of experiment location. It is interesting to note that prior to this series of studies the location of the experimenter had not been considered as a possible influence on eye movement directionality, yet two distinctly different procedures were being used. In research focusing on individual differences and consistency of LEM directionality, the experimenter usually sat facing the subject, while in studies investigating the effect of questions differing in cognitive demand characteristics on an individual's gaze shift, the subject usually sat facing a video camera and sometimes had the experimenter seated behind him or her. In order to investigate

effects of experimenter location, Ehrlichman et al., employed either or both experimenter location situations while examining the effect of question types on lateral and nonlateral eye movements.

In their first experiment, subjects were presented with two sets of 40 questions each: a spatial set (visual imagery, spatial concepts, humming musical phrases) and a verbal set (syntactic and semantic language use, logic). They sat alone in an experimental room, facing a video camera lens, and communicated with the experimenter via a microphone system. The first eye movement following completion of a question was recorded on videotape and later scored for direction of gaze shift. Data analyses indicated significantly more up and stare eye movements for spatial questions and more down movements for verbal questions. Contrary to predictions from Kinsbourne's OMS model, there was no significant effect of questions on the lateral direction of eye movements.

Because the pattern of their results were inconsistent with the bulk of previous eye movement research (particularly with regard to lateral eye movements), Ehrlichman et al. ran a second experiment in which the more traditional face-to-face interview procedure was used. These authors felt that this procedural change would both enable the experimenter to use eye contact with the subject to increase the chances that the subject's gaze would be in a centered position at the end of the question and in addition would eliminate the possible influence that the instructions used in the first experiment (i.e., to look at the camera until the entire question had been read) may have had on a subject's eye movement behavior. A new group of subjects was administered the same set of questions (except a minor change in the spatial set). The only change in the setting and procedure was that an

experimenter sat directly across from the subject, read the questions, and recorded the direction of the subject's gaze shift. The results of this experiment were similar to those obtained in the first one. That is, verbal questions elicited more downward gazes than spatial questions and there was no significant effect of question type on horizontal eye movements.

Since both experiments failed to show the expected effect of question type on lateral eye movement directionality, a third experiment was run. This time Ehrlichman et al. used both their own questions as well as the questions used by Kocel et al. (1972), and employed both video camera and face-to-face interview conditions for each subject. Consistent with the findings in the previous two experiments, there was no significant effect of question type on lateral gaze shift in either condition of this experiment. The tendency for verbal questions to elicit more downward gazes than spatial questions held only for the authors' questions, and not for Kocel's questions. In addition, stares occurred more frequently to spatial than to verbal questions. Ehrlichman et al. reported a similar pattern of results under two conditions of experimenter location (face-to-face and video camera), and, therefore, the difference in procedure could not account for the continued discrepancy between their findings and those of previous studies. They concluded that the effects of verbal and spatial questions on eye movement directionality appear to be reliable only for the nonlateral (up, down, stare) and not the lateral (right, left) dimension. Moreover, they concluded that Kinsbourne's OMS model of lateral eye movements was not supported by the results of their research. Consequently, like

Galin and Ornstein (1974), Ehrlichman et al. contended that future research on gaze shifts should not be limited to examining and theorizing about only the lateral direction of eye movements.

Practically simultaneous with the Ehrlichman experiments, Gur (1975) was examining the effect of experimenter location on eye movement directionality. However, unlike Ehrlichman, her major emphasis was to study the experimenter location variable as a primary influence on the direction of an individual's eye movements when responding to a series of questions. Furthermore, she was not interested in the vertical dimension of eye movements in the different conditions and, consequently, measured only the lateral direction of gaze shifts. Her experiment employed a within subject design in which each subject served in both experimenter location conditions. The two sessions were separated by a week and were counterbalanced across subjects. Within each session, the subject was administered one of two "equivalent" questionnaires consisting of 60 items: 20 verbal (explanation of proverbs), 20 numerical (solution of arithmetical problems, and 20 spatial (visualization and identification of spatial relationships of familiar places and visual arrangements). In the experimenter-facing-subject condition, the experimenter sat across from the subject, read the questions, and recorded direction of eye movements. In the experimenter-behind-subject condition, the experimenter administered the questions while seated behind the subject and the subject faced a video camera. Eye movements in this latter condition were recorded on video tape and later scored for directionality. Results indicated that in the experimenter-facing-subject condition, subjects tended to move their eyes in a consistent direction irrespective of the nature of the question (i.e., some

subjects moved their eyes predominantly to the right; others moved their eyes predominantly to the left, regardless of the type of question asked). Gur suggested that this finding was consistent with Bakan's (1969, 1971) results. In the experimenter-behind-subject condition, a significant effect of question type on eye movement directionality was found such that verbal questions elicited more right movements, spatial questions elicited more left movements, and numerical questions elicited about equal proportions of right and left movements.

Gur suggested that these findings are consistent with those reported by Kinsbourne (1972). Finally, she classified her subjects as "unidirectional" or "bidirectional" according to the number of eye movements in a particular direction within a particular condition, and concluded that direction of gaze shift in response to questions is determined by both problem type and the individual's characteristic preference for use of a certain hemisphere. The influence of the first factor seemed to be maximized in the experimenter-behind-subject condition, while the experimenter-facing-subject condition seemed to maximize the second factor. In an effort to explain the differential effect of experimenter location, Gur suggested that the personal nature of the face-to-face procedure may be a more threatening or anxiety producing situation for the subject than the experimenter-behind-subject condition, resulting in eye movements in the subject's preferred direction (i.e., relying on the hemisphere that is more compatible with his cognitive style) regardless of the type of question. On the other hand, when the experimenter sits behind the subject (making the situation less interpersonal), less anxiety would be elicited, permitting "optimal hemispheric information-processing in accordance with the type of

problem" (as cited in Gur & Gur 1977).

Hiscock (1977a) attempted to replicate Gur's findings regarding the interactional effect of experimenter location and question type on direction of LEMs, and also tried to test her hypothesis concerning the role of anxiety in this effect. Twenty verbal and 20 spatial questions were presented to 81 subjects who had been randomly assigned to one of three experimental conditions: (1) "low anxiety" condition, in which questions were presented via a tape recorder positioned directly behind the subject (designed to replicate previous studies in which the experimenter sat behind the subject); (2) "high anxiety" condition, identical to the first except subjects were given instructions designed to be anxiety inducing (i.e., "questions are part of an intelligence test, the results of which will be publically announced"); and, (3) "face to face" conditions in which questions were administered by an experimenter seated directly in front of the subject (designed to replicate face to face procedures in previous studies). Electro-oculography (EOG) was used to record eye movements.[6] The first eye movement following each question was scored for its horizontal component. Subjects were given scores for verbal and spatial questions that represented the proportion of the LEMs made to the right.

Results confirmed Gur's findings that consistency of eye movement direction is accentuated in the face to face condition. That is, subjects tended to look consistently to one side or the other when the experimenter was present than when he was absent. However, unlike Gur's

[6]Interestingly, although Galin and Ornstein (1974) had suggested that a direct, quantitative measure of eye position during reflective thinking--such as EOG--might provide an answer to discrepancies between LEM studies, Hiscock was the first to utilize this procedure to measure the LEM phenomenon.

hypothesis about the role of anxiety in this LEM consistency, Hiscock found no evidence that anxiety underlies the effects of the face to face condition. Subjects in the face to face condition and in the low anxiety condition did not differ in their responses to an adjective rating scale assessing anxiety, but did differ significantly from the subjects in the high anxiety condition (confirming the effectiveness of the anxiety manipulation in the experiment). In addition, there was no difference between low anxiety subjects and high anxiety subjects on consistency of eye movement scores.

With regard to the effect of question type on LEMs, Hiscock reported that the percentage of right movements was not significantly different for verbal and spatial questions, regardless of experimental condition. These findings are contrary to those reported by Gur, in which question type differentially affected eye movement directions in her experimenter behind subject condition, but are consistent with Ehrlichman et al.'s, observation of both absence of experimenter location effect and question type effect on horizontal/lateral eye movements. Also consistent with Fhrlichman's study are Hiscock's findings that spatial questions elicited fewer lateral eye movements (more nonlateral) than verbal questions, replicating a significant effect of question type on the nonlateral dimension of eye movements. (Unfortunately, Hiscock's EOG methodology did not differentiate types of nonlateral movements, so more precise relationships were not delineated.)

Berg and Harris (1980) attempted a second replication of Gur's study and, like Hiscock (1977a), tried to test Gur's hypothesis about the role of anxiety in LEM directionality. Utilizing a within subjects design, each of the 48 subjects participated in each of three

conditions of this experiment. The three conditions were nearly identical to those used in Hiscock's study, with only minor procedural differences: (1) standard experimenter behind subject condition in which the experimenter sits behind the subject while the subject faces a video camera lens; (2) standard experimenter facing subject condition with video camera located directly above the experimenter, and, (3) stress condition which uses the standard experimenter behind subject procedure but a new experimenter administers the questions and makes stress inducing comments during the condition. Sixty verbal and 60 spatial questions were randomly assigned to six forms each consisting of equal numbers of verbal and spatial questions. Two forms were then administered in each experimental condition. Initial eye movements were scored for their lateral and nonlateral (stare) components following question presentation. In addition, the total duration of all directional eye movements occurring during a ten second time period between completion of question and start of subject's response was scored. The results of this study were both consistent and inconsistent with previous research. Similar to Hiscock's results, there was no difference between the standard experimenter facing subject and experimenter behind subject conditions regarding anxiety ratings, thus failing to support Gur's hypothesis that the former condition is more stress producing than the latter. Contrary to both Gur's and Hiscock's findings, in this study direction of eye movements was not significantly related to either experimenter location or to stress manipulation. Furthermore, there were no question type effects on lateral direction of eye movements, regardless of condition.

The results of the data reflecting percentage of <u>duration</u> of right movements in the ten second post question/pre-response period indicated that, as with initial movement scores, neither experimenter position or stress condition was differentially related to direction of eye movement. However, significantly more right looking and stares occurred with spatial questions and significantly more left looking occurred with verbal questions. These results on duration of eye movements are consistent with trends noted in Ehrlichman's study where lateral eye movements to verbal and spatial questions tended to be ipsilateral to the presumably activated hemisphere. At the same time, however, these results are directly contrary to hemispheric activation models of LEM directionality. Berg and Harris concluded that the discrepancies between their findings and those of earlier eye movement studies "suggest that the lateral eye movement phenomenon is extremely sensitive to task, subject, and environmental variables . . ." (p. 92), and, that basic methodological inconsistencies in the LEM research account for a major part of the variability in results reported.

In summary, recent reflective eye movement research has focused on the effect of question type on direction of gaze shift, and has reported that questions varying in cognitive content and/or affective quality significantly affect eye movements in either or both the horizontal and the vertical directions. The interactive effects of experimenter location with question types on gaze shift directionality has also been examined. The variability in results between these studies have been attributed to both methodological discrepancies between studies, as well as to inadequate or inaccurate theoretical models to guide interpretation of results.

<u>Summary of reflective eye movement research.</u> It is apparent that considerable differences in both methodological approach and interpretation of results have led to controversy in relating the reflective eye movement phenomenon to cognitive functioning. However, despite this, certain relationships are seemingly stable enough to emerge from the different studies. It has been demonstrated that for at least some individuals, eye movement shifts occur in a fairly consistent direction. Various personality, physiological, and cognitive differences between these individuals, classified as either left movers or right movers according to the direction of gaze shifts, have indicated that right movers tend to be more externally oriented, less susceptible to hypnosis, and perform better on the quantitative sections of the SAT than left movers. These differences have been attributed to differential dependence on the cerebral hemisphere contralateral to the direction of the majority of gaze shifts (Bakan 1969, 1971). The role of cerebral hemispheres has been examined more directly by utilizing questions designed to engage either the right or the left hemisphere. Results of these studies have revealed that direction of gaze shift is related to the kind of question used. For example, verbal and numerical questions seem to elicit eye movements to the right while spatial and musical questions seem to elicit eye movements to the left. These findings have suggested that direction of gaze shift is contralateral to the hemisphere that is processing the particular question (Kinsbourne 1972). Because of these consistencies with regard to hemispheric specialization and the potential important implications of the right-left differences in cognitive processing, it seems desirable to pursue further investigation of the LEM phenomenon.

Although the aforementioned consistencies exist across a number of reflective eye movement studies, there are, at the same time, numerous discrepancies that have been reported. For example, both Kocel et al. (1972) and Kinsbourne (1972) reported more right movements for verbal questions than for spatial questions and no differences between the number of right and left movements for numerical questions, while Weiten and Etaugh (1974a,b) reported that both their verbal and numerical questions elicited a greater proportion of movements to the right than did their spatial and musical questions. Moreover, a number of authors failed to find any differential effect of verbal or spatial questions on lateral eye movements (Ahern & Schwartz 1979; Crouch 1976; Ehrlichman et al. 1974), and in some cases, investigators have reported gaze shifts in opposite directions to those predicted by a hemispheric activation hypothesis (Berg & Harris 1980; Ehrlichman et al. 1974). Still other investigators have reported significant effects of question type on nonlateral eye movements (Ehrlichman et al. 1974; Galin & Ornstein 1974; Hoffman & Kagan 1977; Tucker et al. 1978). In fact, in a review of LEM research occurring between 1972 and 1977 in which the differential effect of question types on eye movements was examined, Ehrlichman and Weinberger (1978) found that over half of the articles reviewed failed to find the predicted pattern of more right LEMs than left LEMs to "left hemisphere" questions, or more left LEMs to "right hemisphere" questions.

To account for these discrepancies in results, both Arneson (note 3) and Ehrlichman and Weinberger (1978) have pointed out the methodological inconsistencies that exist between LEM studies. Briefly, some of the major inconsistencies described by these authors are:

(1) differing numbers and types of reflective questions; (2) utilizing questions which are assigned to differentially engage the hemispheres without some prior independent validation of this assumption; (3) varying location of experimenter (though the bulk of recent research examining this variable reports negligible effects on eye movement patterns); (4) methods of recording and scoring eye movements; and, (5) choosing the salient dimensions (horizontal, vertical) of eye movements as dependent variables. For greater detail regarding each of these methodological issues, the reader is referred to the aforementioned reviews.

While methodological inconsistencies between eye movement studies have accounted for some of the variability in results, numerous researchers have proposed that another source of variability lies in the inadequacy of hemispheric activation models to explain the eye movement phenomenon (cf., Arneson, note 3; Berg & Harris 1980; Ehrlichman & Weinberger 1978). Originally proposed by Bakan (1969) and later adapted and elaborated by Kinsbourne (1972), the hypothesis that eye movement directionality, specifically on the lateral plane of gaze shifts, reflects activation of the functionally asymmetrical hemispheres, provided a parsimonious explanation that was consistent with some of the prevailing theoretical viewpoints for perceptual lateralities. This model was easily applied in those LEM studies which examined only the left-right dimension of gaze shifts, and in which significant effects of question type were found in the predicted direction. However, for studies that utilized both horizontal and vertical dimensions of gaze shift, Kinsbourne's model had to be modified to include the vertical dimension as an equally salient dimension to lateral gazes (i.e., he explained vertical movements as reflecting bilateral activation of

the hemispheres). Yet, this "adapted" model failed to explain the differences between question types and different vertical movements--more downs to verbal questions, more ups and stares to spatial questions. To paraphrase Ehrlichman et al. (1974) the apparent inadequacy of his theory to account for the entire set of differences in eye movements obtained by different types of questions raises doubts about its explanatory power.

An additional facet of Kinsbourne's OMS model that has been challenged is the assumption that reflective eye movements occur as a result of neurophysiological mechanisms. That is, he proposed that intrahemispheric "cross talk" between cognitive processing and cortical mechanisms for orienting or gaze determines direction of gaze during reflective thinking. Ehrlichman and Weinberger (1978) suggest that perhaps the OMS model is relevant for the lateral direction of eye movements, provided they occur, but to presume a neurophysiological mechanism actually "causes" differential LEM shifts is, in their opinion, an oversimplified explanation: ". . . there is no clear indication how hemispheric activation produced by cognitive activity 'spills over' to the frontal fields. Thus, the description of eye movement control that has been proposed to account for LEMs appears to be more metaphor than mechanism . . ." (p. 1097). The heuristic value of such a model is recognized, but these authors concluded that additional explanations for the LEM phenomenon are needed.

The Present Study

This study was designed to examine further the reflective eye movement phenomenon and to introduce an alternative explanatory model

for the occurrence and direction of eye movements to reflective questions. This model, the Visual Half Field Shut Down (VHF SD) theory, has recently been suggested by Tucker (personal communication) and proposes that individuals divert their gaze in order to "shut down" information input to the visual half fields contralateral to the hemisphere that is functionally prepared to process the content of the reflective question. Like the OMS model, this model presupposes differential specialization of the cerebral hemispheres for cognitive mode and assumes that the direction of the LEM shift may often indicate relative hemispheric usage. Also like the OMS model, the VHF SD theory involves a shift in attention to account for the occurrence of eye movements. However, it does not require neurophysiologically based activation overflow mechanisms to generate these shifts. Instead, it suggests that individuals engage in functionally relevant behavior when they shift their attention to selectively preclude input of additional, potentially distracting information from their visual field during reflection.

While there has been no direct mention of this theory in the LEM literature to date, there have been a few indirect references to the plausibility of such an explanatory model. For example, Bramwell (1928) observed that individuals often look up when responding to questions in order to eliminate visual stimuli that might interfere with their train of thought. Similarly, Teitelbaum (1954) suggested that individuals engage in eye movement behavior to avoid potentially distracting perceptual input that will interfere with mental concentration. Meskin and Singer (1974) described two models that appear to be consistent with the VHF SD theory. The first is the "general cognitive model of eye shift" and it suggests that eye movement directionality is

determined primarily by the complexity of the visual stimulus field facing the subject. This model predicts that eye movements either fixate on a minimally stimulating portion of the external field, or close, in order to avoid overloading the visual system. A second model, "general arousal model," suggests that reflective thinking or imagery "arouses" the organism and predicts that the frequency of eye movements will differ with the difficulty/emotionality of the reflective questions (this latter model predicts no consistency in direction of eye movements). Interestingly, in a study comparing these and the more traditional hemispheric asymmetry model of eye movements, Meskin and Singer reported that more eye movements occurred to "extended search" questions than to "minimal search" questions (consistent with their general arousal model). Their data failed to support either of the other models. However, Berg and Harris (1980) utilized Meskin and Singer's general cognitive model to explain the nonlateral, stare, responses to spatial questions in their study, such that, "during the solution of spatial problems, staring may reduce interference from the external field with the internally generated image" (p. 92). Ehrlichman and Weinberger (1978) suggested a similar relationship between stares and the effect of external stimuli, and, as was stated above, have supported the development of a new explanatory hypothesis to supplement what they feel to be the inadequate explanatory power of the OMS model for the LEM phenomenon.

Statement of the Problem

In order to provide a more precise explanation of the lateral eye movement phenomenon and its relationship to cognitive functioning, the present study was designed to examine the effectiveness of the

Visual Half Field Shut Down theory to explain occurrence and direction of LEMs to reflective questions.

Utilizing electro-oculography (EOG) to record eye movements, reflective eye movements were observed in two phases of this experiment. In phase I, eye movements were recorded while subjects responded to verbal and spatial questions with their eyes open (standard condition) and with their eyes closed. In line with the VHF SD theory, it was predicted that fewer eye movements would be made while the subjects have their eyes closed because visual distraction is reduced to a minimum. In phase II, eye movements were recorded while subjects responded to verbal and spatial questions in the standard condition, with the addition of distractor stimuli presented in their visual field while they processed/responded to the questions. In accordance with the VHF SD theory, it was predicted that more eye movements (and more extreme eye movements) would be made when visual distractors were added.

In both phases of this study, more right LEMs were expected to occur to verbal question sets and more left movements were expected to occur to spatial question sets. Furthermore, the nature of the distractor stimuli (verbal versus nonverbal) in phase II was hypothesized to strengthen this differential directional shift when type of distractor was matched with type of question (i.e., verbal question-verbal distractor) and to attenuate this directional shift when the type of distractor and question type were mixed.

CHAPTER II

METHOD

Subjects

Subjects were 48 undergraduate students (32 female, 16 male) enrolled in undergraduate psychology courses at the University of North Dakota. For their participation in this experiment each subject received research credit which could be applied toward meeting the courses' research participation requirements. All subjects were right handed (by self-report) and were recruited for a study of "how the brain processes information" with no mention of eye movements.

Materials

Reflective Questions

Forty verbal and 40 spatial questions that were representative of verbal and spatial questions used in other LEM studies were developed to elicit eye movements in the present study. Verbal items consisted of questions designed to require the use of logic, proverb interpretation, and syntactic and semantic knowledge of language. Examples of verbal items are: (1) "Solve this problem: Al is smarter than Sam and Al is duller than Rick. Who is smartest?"; (2) "Explain: It's better to have a good enemy than a bad friend."; (3) "Make up a sentence using the words 'present' and 'quest'."; and, (4) "Define charity." Spatial items consisted of questions designed to elicit

use of spatial concepts, memory of an item, and various kinds of visual imagery. Examples of spatial items are: (1) "A pentagon is a five-sided figure. Are any two sides parallel to each other?"; (2) "In which direction does Abraham Lincoln face on a penny?"; (3) "On your student I.D. card, where is your name relative to your student number?"; and, (4) "If you were traveling from New York to San Francisco which direction would you go?"

The questions were divided into four sets of ten verbal and ten spatial questions each. The cognitive content, level of complexity, and sentence structure were similar between the four sets (Appendix A). Each of these 20 question sets was then randomly assigned to one of four experimental conditions in this study.

Five neutral questions designed to minimize content and structure constraints were developed as warm-up questions to be used at the beginning of the first experimental condition (Appendix B).

Distractor Stimuli

Two sets of distractor stimuli were developed for Phase II of this study. One set was designated "verbal distractors" and consisted of 20 slides each containing a vertical arrangement of three different four letter nouns. These nouns were selected from a listing of words that have an occurrence in general reading materials of at least 50-100 per million (Thorndike & Lorge 1944) and were randomly assigned to a three word grouping (Appendix C). The second set of distractors was designated "nonverbal distractors" and consisted of 20 slides each containing a black and white photograph of a human face unknown to the subject. Similar to a procedure used by Moscovitch (1976), ten male

and ten female photographs from a 1971 college yearbook were selected (see Appendix D). Both verbal and nonverbal distractor stimuli filled approximately the same amount of space horizontally and vertically when projected onto an opaque screen.

Apparatus

A Grass Model 79 Polygraph coupled to a direct current (DC) preamplifier was used to record direction and extent of eye movements obtained via electro-oculographic (EOG) methods. Bipolar recordings of eye movements was obtained utilizing two silver-silver chloride surface electrodes firmly attached to the temple region at a point located slightly behind the outer canthus of each eye. An event marker on the polygraph was used to indicate the beginning and the end of each question as well as the point at which subjects initiated a verbal response to the questions posed.

Stimulus slides were presented by a Kodak Carrousel projector.

Procedure

This study was divided into two phases. Phase I examined eye movement directionality while the subject responded to verbal and spatial reflective questions both with his eyes open and with his eyes closed. Phase II introduced verbal and nonverbal distractors and examined the effect of these distractors on eye movement directionality while the subject responded to verbal and spatial questions with his eyes open. Each phase of this study used a two by two (condition x question type) within subjects design.

The entire experiment took place in an experimental room which was arranged to provide a homogeneous and symmetrical visual field for

the subject. The subject was seated facing an opaque, rear projection screen centered approximately four feet from him. This screen was, in turn, centered in front of a one-way mirror covered by black mesh curtains. The experimenter and experimental apparatus were located in a small room on the other side of the mirror. An audio amplifying system allowed the experimenter and subject to communicate with each other throughout the experiment.

Upon greeting the subject at the appointed time, the experimenter seated the subject and introduced herself. In an attempt to provide a casual and relaxed atmosphere, the experimenter then engaged the subject in a friendly conversation and gathered some non-threatening personal data from him (e.g., college major, hometown, outside interests). Following this introductory period, the subject was given the following brief description of the general experimental procedures:

> The purpose of this study is to investigate the ways in which the human brain processes information. The way we will be doing this is by recording electrical currents from two locations on your head while you respond to a series of questions. These electrical currents will be picked up through these electrodes (demonstrate) which will be placed here on each of your temples (demonstrate). These electrodes are simply <u>receivers</u> of electrical current occurring while you think about the questions I will ask you. They do not <u>emit</u> or send out any kind of current, so there is no danger of you receiving any shock by having these placed on you.
> There are four sections to this study. Generally, in each section I will ask you to face this screen (demonstrate) while I ask you to respond to a number of questions. I will be seated in a back room monitoring the electrical recording equipment. Once the experiment gets started, we will communicate through an intercom system. I will give you more specific instructions about each section when it begins.

The subject was asked if he had any questions and the experimenter responded as fully as possible to these questions without divulging

the experimental hypotheses. The experimenter than affixed the electrodes and made sure the subject was seated comfortably before she left the experimental room.

Phase I

Phase I of this study had two conditions. In the first condition, the subject's eyes remained open while he responded to a set of ten verbal and ten spatial reflective questions. In the second condition, the subject's eyes were closed while he responded to a second set of ten verbal and ten spatial questions. Order of condition and order of question were counterbalanced between subjects with the restrictions that the verbal and the spatial questions be presented in blocks of ten each and that when verbal questions were presented first in one condition, they were presented first in the second condition.

For the eyes open condition, the subject was given the following instructions:

> I am going to ask you a series of questions. Before the start of each question a grey dot will appear on the screen in front of you. Please maintain eye contact (focus) on that dot until I have completed asking the question. You may look anywhere you wish when the question has been completed and the dot leaves the screen. I will be recording your responses, so try to answer each question as best you can. Any questions?

Following these instructions, a slide projecting a grey dot to the center of the opaque screen was presented. In order to ensure that the subject understood the task, five neutral questions were asked for which responses were not recorded and during which procedural clarifications were made where necessary. Upon completion of the neutral questions, the ten verbal and ten spatial questions were asked.

For the eyes closed condition, the subject was instructed as follows:

> In this phase of the experiment I want you to close your eyes while I ask you a series of questions and I want you to keep your eyes closed while you make your responses. At the beginning of each new question I will say "focus" at which time I want you to direct your focus--with your eyes still closed--to the area of the screen in front of you where this grey dot is now positioned (demonstrate). Please try to maintain this focus until I have finished asking the question. I will be recording your responses to these questions, so try to answer each question as best you can. Any questions?

A second set of ten verbal and ten spatial questions was then presented to the subject.

Phase II

Phase II of this study was designed to examine the effect of verbal versus nonverbal (faces) distractors on LEMs made to verbal and spatial questions. To study this effect, 20 verbal distractor slides were used in one condition and 20 nonverbal distractor slides were used in the second condition. In both conditions, the subject's eyes remained open while he or she responded to the question sets. Order of condition and order of question types were counterbalanced between subjects with the same restrictions on question order as described for Phase I of this study.

Instructions preceding the verbal distractor condition were as follows:

> In this part of the experiment I am going to ask you a number of questions. Before the start of each question a grey dot will appear on the screen in front of you. Please keep focused on this dot until I have completed asking the question. Upon completion of the question, the grey dot will leave the screen and will be immediately replaced by a slide containing three words. You should ignore these distractor

> words until you have responded to the questions. I will be recording your responses, so please try to answer each question as best you can. Any questions?

Following completion of these instructions, a third set of 20 reflective questions (ten verbal, ten spatial) were administered.

For the nonverbal distractor condition, the subject was given the same instructions used in the verbal distractor condition with the exception that instead of describing the distractor slides as containing "three words," these slides were described as being "photographs of human faces" which the subject was to ignore until he or she had responded to the questions. As in other conditions, a set of ten verbal and ten spatial questions was asked each subject.

Upon completion of both phases of this experiment, the experimenter calibrated the degree of visual angle and corresponding pen displacement on the polygraph by having the subject direct his gaze to several fixed points in the visual field (e.g., center, edge of opaque screen, edge of curtain, edge of wall for both the right and left side of the visual field). This procedure enabled the experimenter to calibrate the recording apparatus without previously directing the subject's attention to the fact that reflective eye movements had been recorded. The experimenter then joined the subject, removed the electrodes, and asked the subject to complete two brief paper and pencil questionnaires: (1) the Crovitz and Zener Handedness Inventory (1962) to validate the subject's self-reported right handedness (Appendix E), and (2) an Experimental Feedback Questionnaire to determine if the subjects were naive to the purpose of the study, and to gather information about their experiences in the different conditions of the study (Appendix F).

Scoring of Eye Movements

The first eye movement following each question was scored as a "valid" lateral eye movement (right, left) provided it had a horizontal component of at least 5° visual angle in magnitude (Kinsbourne 1972; Hiscock 1977a; Schwartz et al. 1975); that it occurred at least one second prior to the subject's verbal response to the question (in order to minimize the scoring of eye movements that tend to accompany verbal encoding processes which occur immediately preceding verbal responding) (Ahern & Schwartz 1980; Hiscock 1977a); and, that it occurred within two seconds after completion of the question. Valid "nonlateral" trials consisted of those responses made in which there was no lateral eye movement elicited within a two second period following completion of the question.

Eye movement responses were scored "invalid" if eye movements occurred prior to completion of the question and were considered "unscoreable" if a steady baseline was not maintained for at least one second prior to the beginning of the question.

The EOG records were divided evenly between two independent judges and scored according to the criteria stated above. Inter-judge reliability was established on several randomly selected protocols and agreement between the two judges was .92 for valid trials and .85 for invalid and unscoreable trials.

CHAPTER III

RESULTS

Validity Check on Subjects' Self-reported Right-handedness

The scores on Crovitz and Zener's (1962) twenty-item questionnaire to assess handedness ranged from 14 to 30 ($\overline{X}$ = 19.85) across the 48 subjects in this experiment. These scores were well within the range obtained in Crovitz and Zener's norming sample in which subjects whose scores were between 14 and 40 were classified as right-handed.

Incidence of Eye Movements

The number of possible eye movement trials in this study was 3840. Of this total possible, 2620 met the eye movement scoring criteria as valid eye movements, while the balance consisted of trials during which eye movements were made prior to the completion of the reflective questions. Of the 2620 valid trials, 1260 (about 48%) elicited lateral eye movements of 5° or more. The lateral eye movements consisted of 890 right LEMs (about 70%) and 370 left LEMs (about 30%). The remaining 1360 valid trials (about 52%) consisted of nonlateral eye movement responses.

Effects of Question Type and Experimental Condition on Direction of Lateral Eye Movements

In order to assess the effects of question type (verbal, spatial) and experimental condition (eyes closed, eyes open, verbal distractor,

nonverbal distractor) on the number and direction of valid lateral eye movements, a two-way repeated measures analysis of variance (question type x condition) was computed for each of the eye movement directions. The frequency of each type of eye movement was expressed as a proportion of the total number of scoreable trials. This was done for the ten verbal and ten spatial questions within each condition for each subject.

Table 1 summarizes the mean proportion of eye movements to the right and to the left for each question type collapsed across experimental condition.

TABLE 1

MEAN PROPORTION OF EYE MOVEMENTS TO THE RIGHT AND TO THE LEFT FOR VERBAL AND SPATIAL QUESTIONS

Question Type	Direction of Eye Movements Right	Left
Verbal	.389	.146
Spatial	.313	.151
F*	7.28	.05
p	.01	.82

*df = 1,47.

As is observed in Table 1, the hypothesis that the cognitive content of reflective questions would differentially effect lateral eye movement directionality was supported for right eye movements only. Consistent with previous LEM research (as reviewed in Ehrlichman & Weinberger 1978), significantly more right eye movements were made to verbal than to spatial questions. The prediction that more left LEMs would be made to spatial than to verbal questions was not supported.

The effect of experimental condition, across question type, on direction of lateral eye movements is presented in Table 2. As is shown in Table 2, experimental condition had a significant overall effect on the number of right eye movements made to reflective questions. This main effect of condition was not evident for left eye movements.

TABLE 2

MEAN PROPORTION OF EYE MOVEMENTS TO THE RIGHT AND TO THE LEFT FOR EACH OF THE EXPERIMENTAL CONDITIONS

Condition	Direction of Eye Movement Right	Left
Eyes Closed	.158	.108
Eyes Open	.322	.181
Verbal Distractor	.465	.151
Nonverbal Distractor	.460	.153
F*	26.70	2.20
p	.01	.86

*df = 3,47.

On the basis of a priori hypotheses concerning individual condition effects on the number and direction of lateral eye movements, specific differences between condition means were examined using multiple t tests. Table 3 summarizes the comparisons between conditions for right and left eye movements (p=.05 for each comparison). The results indicate that significantly fewer right eye movements were made in the eyes closed condition than in any of the other experimental conditions and that significantly fewer left movements were made during the eyes closed condition than during the eyes open condition. Significantly more right eye movements were made during each of the distractor conditions than

TABLE 3

SUMMARY OF THE t TESTS ON DIFFERENCES BETWEEN CONDITION MEANS FOR NUMBER OF RIGHT AND LEFT LATERAL EYE MOVEMENTS

Larger Condition Mean	Smaller Condition Means 1	2	3	4
1. Eyes Closed				
2. Eyes Open	R/L			
3. Verbal Distractor	R	R		
4. Nonverbal Distractor	R	R		

NOTE: R=Right, L=Left. Each entry reflects a significant difference for that eye movement direction between the column and the row conditions.

were made during the eyes open condition. The remaining comparisons failed to reach significance.

Table 4 presents the mean proportion of lateral eye movements as a function of the interaction between question type and experimental condition. Although interactions did not reach statistical significance for either right or left movements, several a priori, theoretically-based comparisons of special differences were computed utilizing multiple t tests. In accordance with the Visual Half Field Shut Down (VHF SD) theory, predictions were made concerning the additive effect of type of question and type of distractor on the frequency and direction of lateral eye movements. More specifically, it was hypothesized that the combination of verbal questions and verbal distractor condition would produce more right movements than other question type-condition combinations. Similar predictions were made concerning

TABLE 4

MEAN PROPORTION OF RIGHT AND LEFT EYE MOVEMENTS AS A FUNCTION OF QUESTION TYPE AND EXPERIMENTAL CONDITION

	Direction of Eye Movements	
	Right	Left
VERBAL QUESTIONS		
Condition		
Eyes Closed	.169	.114
Eyes Open	.364	.173
Verbal Distractor	.517	.139
Nonverbal Distractor	.507	.158
SPATIAL QUESTIONS		
Condition		
Eyes Closed	.146	.102
Eyes Open	.281	.190
Verbal Distractor	.414	.163
Nonverbal Distractor	.413	.149
F*	.41	.20
p	.75	.89

*df = 3,47.

left movements and the spatial question-nonverbal distractor condition combination. Furthermore, it was predicted that mixed combinations (i.e., verbal question-nonverbal distractor condition or spatial question-verbal distractor condition) would attenuate the aforementioned effects.

As hypothesized, significantly more right eye movements were made during the verbal question-verbal distractor condition combination than during verbal question-eyes closed ($t(47)=5.35$, $p < .05$), verbal question-eyes open ($t(47)=2.12$, $p < .05$), spatial question-eyes closed ($t(47)=6.18$, $p < .05$), and spatial question-eyes-open ($t(47)=$

3.41, $p < .05$). Contrary to prediction, there was no significant difference between the number of right movements made during the verbal question-verbal distractor condition combination than during either of the mixed question-condition sets ($t(47) = .12$, n.s., for verbal question-nonverbal distractor; $t(47) = 1.36$, n.s., for spatial question-verbal distractor). Also contrary to prediction, the comparisons between the effect of the combined spatial question-nonverbal distractor condition and the other possible question type-condition combinations on the number of eye movements to the left were all non-significant (t values ranged between .18 and 1.05, n.s. for each comparison).

Effects of Question Type and Experimental Condition on Extent of Eye Movement Directionality

To assess the extent of gaze shift, the average degree visual angle of right and left lateral eye movements was individually computed in each condition and for each set of verbal and spatial questions. Trials in which no lateral eye movements were made were scored as zero extent. A two-way repeated measures analysis of variance (question x condition) was computed for each lateral eye movement direction.

Table 5 summarizes the mean extent of eye movement shift to the right and to the left for each question type (collapsed across condition). As is shown in Table 5, there was no significant effect of question type on extent of lateral eye movements made to either the right or the left.

The effect of experimental condition, across question type, on extent of lateral eye movements in presented in Table 6. The results indicate a significant effect of experimental condition on the average degree visual angle of both right and left eye movements.

TABLE 5

EFFECT OF QUESTION TYPE ON MEAN DEGREE VISUAL ANGLE OF GAZE SHIFT

Question Type	Direction of Eye Movements Right	Left
Verbal	10.24	5.27
Spatial	10.30	5.61
F*	.01	.25
p	.50	.50

*df = 1,47.

TABLE 6

EFFECT OF CONDITION ON MEAN DEGREE VISUAL ANGLE OF GAZE SHIFT

Condition	Direction of Eye Movement Right	Left
Eyes Closed	3.84	3.27
Eyes Open	9.95	6.91
Verbal Distractor	13.45	5.67
Nonverbal Distractor	13.85	5.92
F*	16.84	3.35
p	.0001	.02

*df = 3,141.

Specific differences between condition means were investigated utilizing multiple t tests. Table 7 summarizes these comparisons (p= .05 for each comparison). As is observed in Table 7, significantly smaller (less extreme) right eye movements were made during the eyes closed condition than during any of the other experimental conditions. Significantly less extensive left movements were made during the eyes

closed condition than during the eyes open condition. The remaining comparisons failed to reach significance.

TABLE 7

SUMMARY OF THE t TESTS OF DIFFERENCES BETWEEN CONDITION MEANS FOR EXTENT OF RIGHT AND LEFT LATERAL EYE MOVEMENTS

		Smaller Condition Means			
		1	2	3	4
Larger Condition Means	1. Eyes Closed				
	2. Eyes Open	R/L			
	3. Verbal Distractor	R			
	4. Nonverbal Distractor	R			

NOTE: R=Right, L=Left. Each entry reflects a significant difference for that eye movement direction between the column and the row conditions.

Table 8 presents the mean extent scores for left and right lateral eye movements as a function of the interaction between question type and condition. The interactional effect of question type and condition on extent of eye movements was not significant for either left or right movements. However, because this is the first study in which LEM extent data has been presented, all possible comparisons were completed for these nonsignificant interaction effects. Larger left LEMs occurred during the spatial question-eyes open condition than during any other question-condition combination (t tests ranged from 1.98 to 4.15, $p < .05$ for each), with the exception of the verbal question-nonverbal distractor condition, in which there was no significant differences in extent measures ($t(141) = 1.62$, n.s.).

TABLE 8

MEAN EXTENT SCORES FOR LEFT AND RIGHT EYE MOVEMENTS AS A FUNCTION OF QUESTION TYPE AND CONDITION

	Direction of Eye Movements	
	Right	Left
VERBAL QUESTIONS		
Condition		
Eyes Closed	3.16	3.75
Eyes Open	10.11	5.45
Verbal Distractor	13.83	5.68
Nonverbal Distractor	13.86	6.16
SPATIAL QUESTIONS		
Condition		
Eyes Closed	4.51	2.78
Eyes Open	9.79	8.33
Verbal Distractor	13.07	5.65
Nonverbal Distractor	13.85	5.68
F*	.46	1.64
p	>.50	.18

*df = 3,141.

Significantly less extensive left LEMs occurred during the spatial question-eyes closed condition than during any other question-condition combination (t tests ranged from 2.03 to 4.15, p <.05 for each) with the exception of the verbal question-eyes closed condition (t(141) = .72, n.s.).

The pattern of significant comparisons of interaction effects for right LEMs parallels nonsignificant trends in the condition main effects. That is, significantly more extensive right eye movements occurred during either distractor condition, regardless of question type, than during verbal question-eyes open condition (t tests ranged

from 2.21 to 2.79, $p < .05$ for each), or spatial question-eyes open condition (t test ranged from 2.45 to 7.51, $p < .05$ for each). Finally, significantly less extensive right eye movements were made during the eyes closed condition, regardless of question type, and all other question type-condition combinations (t tests ranged from 3.94 to 7.98, $p < .05$ for each).

Effects of Question Type and Experimental Condition on Nonlateral Eye Movements

Even though this initial examination of the VHF SD theory for reflective lateral eye movements does not make predictions regarding the effects of question type and experimental condition on nonlateral eye movements, the finding that nearly 52% of the valid trials made in this study were scored as having no lateral component suggested that additional analyses may be warranted. Consequently, a two-way repeated measures analysis of variance (question type x condition) was performed for the category of eye movements scored as "nonlateral." The mean proportion of nonlateral trials within each experimental condition and question category are presented in Table 9. Consistent with previous eye movement literature (as reviewed by Ehrlichman & Weinberger 1978), more nonlateral trials occurred to spatial than to verbal questions, $F\ (1,47)=5.12$, $p= .02$. This means that apparently spatial questions elicit more vertical movements (up, down) and/or stares than do verbal questions. Furthermore, the number of nonlateral trials varied significantly among experimental conditions, $F\ (3,47)=25.59$, $p= .0001$. T tests were performed to assess the sources of the significant condition effect. Results indicate that significantly more nonlateral trials occurred during the eyes closed condition than during any of

TABLE 9

MEAN PROPORTION OF NONLATERAL TRIALS WITHIN EACH EXPERIMENTAL CONDITION AND QUESTION CATEGORY

Condition	Question Type Verbal	Spatial
Eyes Closed	.675	.711
Eyes Open	.663	.529
Verbal Distractor	.344	.424
Nonverbal Distractor	.334	.418

the other conditions (t tests ranged from 4.12 to 6.44, $p < .05$ in each case). Significantly more nonlateral trials occurred during the eyes open condition than during either the verbal or the nonverbal distractor conditions ($t\ (47)=2.14$, $p < .05$, and $t\ (47)=2.28$, $p < .05$) respectively). There was no difference between distractor conditions with regard to nonlateral trials ($t(47)= .16$, n.s.). In the analyses of nonlateral responses, the question type by condition interaction was nonsignificant, $\underline{F}\ (3,47)= .14$, $p= .94$.

Other Findings

In an attempt to minimize the scoring of lateral eye movements that might reflect verbal encoding prior to responding to reflective questions, eye movements were not scored as valid if they occurred within one second prior to the subject's verbal responses (similar to procedures used by Hiscock 1977a; and Kinsbourne 1972). To examine whether right movements occur more frequently during this one-second exclusion time, the number of lateral and nonlateral eye movements that occurred during this time interval of each trial were summed. Only 28%

of the movements made were in the expected (right) direction. Left LEMs comprised 24% of the movements which occurred just prior to verbalization and 48% of the trials during this time were scored as nonlateral.

Upon completion of this experiment, subjects were administered a post-experimental feedback questionnaire (Appendix F) and were asked several questions regarding their experiences during the experiment. A large proportion of the subjects (about 43%) indicated that during the eyes closed condition it was difficult for them to "focus" while the reflective questions were being read to them. In addition, about 13% of the subjects indicated that while their eyes were closed, they felt their "eyes drifting." Fifteen subjects (about 31%) reported that neither the faces in the nonverbal distractor condition or the words in the verbal distractor condition were distracting. Instead these subjects simply ignored the distractors by "looking through them." Another group of subjects (representing about 19% of the total sample) indicated that the facial (nonverbal distractors) were more distracting than the verbal distractors. A summary of the subjects' responses pertaining to their experiences during the different conditions in the study is presented in Appendix G.

CHAPTER IV

DISCUSSION

This study was designed to introduce and test the Visual Half Field Shut Down (VHF SD) theory of reflective lateral eye movements. According to this theory, eye movements are made during reflective thinking in order to selectively shut-down, or decrease, interference from potentially distracting stimuli in an individual's visual field. The direction of these eye movements is assumed to reflect relative functional specialization of the cerebral hemisphere contralateral to the direction of the gaze shift. A lateral eye movement produces a decrement in visual input which is specific to the contralateral hemisphere. If during "reflective" thinking visual input is distracting, the directionality of the input shut-down may be relevant to the lateralization of the brain function involved in the reflective thought.

Various aspects of this theory received support in the results of this experiment, particularly with regard to the effect of visual distraction on both the frequency and the extent measures of lateral eye movements. However, other properties were not supported and challenged the ability of the VHF SD theory to account for the many complexities of the gaze shift phenomenon. The results will be discussed according to specific predictions made by the VHF SD theory concerning the effects of question type and presence or absence of visual distraction on (1) the frequency of lateral eye movements and (2) the extent

of lateral eye movements. Additional findings not specifically related to the VHF SD model will then be examined. Finally, implications of these findings for future lateral eye movement research will be explored.

VHF SD Theory and Predictions Concerning the Frequency of LEMs

The VHF SD theory makes three predictions regarding the effects of question type and/or the presence or absence of visual distraction on the frequency and direction of LEMs: (1) verbal and spatial questions will differentially effect the number of eye movements made to the right and to the left, respectively; (2) more eye movements will be made when distractors are present than when they are absent; and, (3) the type of question will interact with the type of distractor (verbal, nonverbal) to produce more LEMs when question type and distractor type are the same (i.e., verbal-verbal), than when they are different (i.e., verbal-nonverbal).

Effect of Question Type

The VHF SD theory must assume that the frequency and direction of LEMs will reflect hemispheric specialization for question type. That is, more right LEMs will occur to verbal than to spatial questions, and, conversely, more left LEMs will occur to spatial than to verbal questions. The data in this study support the question type effect for right LEMs only. The effect of question type on left LEMs was not significant. Interestingly, the finding of significantly more right LEMs to verbal than to spatial questions is consistent with findings reported in a number of studies and has tended to be one of the more frequently reported results in the LEM literature (as reviewed in Ehrlichman and

Weinberger 1978). On the other hand, relatively few researchers have reported results concerning question effects and left LEMs. Only two reported more left LEMs to spatial than to verbal questions (Gur 1975; Kinsbourne 1972). Three studies have reported more left movements to emotional than to nonemotional questions, but failed to find a significant effect of cognitive aspects of their question on LEMs (Ahern & Schwartz 1979; Schwartz et al. 1975; Tucker et al. 1977). The remaining authors who have cited left LEM data have reported findings consistent with the results of this study, that is, no significant effect of question type on the number of left LEMs (Ehrlichman et al. 1974; Galin & Ornstein 1974; Säring & Von Cramon 1980).

The noticeable sparcity of studies reporting data about both left and right LEM behavior reflects the tendency of investigators in this field to assume that right and left LEMs are perfectly redundant (i.e., what happens with right eye movements is the exact opposite of what happens with left movements). In part, this tendency is reflected in the methods of presenting LEM data. Ehrlichman and Weinberger (1978) have reviewed the various methods of summarizing LEM data that have been used across the various LEM studies and have concluded that the most appropriate way of expressing the LEM behavior is in terms of a percentage right score based on the number of trials in which a right or left LEM occurred. These authors criticize studies that choose to treat right and left LEMs separately (as in the present study): "conclusions about relative degree of right or left LEMs for verbal versus spatial questions cannot be inferred from simple tests of differences in the frequencies of right and left movements" (p. 1088). However, for good empirical research the basic observations should first be recorded,

then inferences on their significance can be drawn. When presented with a question requiring reflective thought, a subject may look in several directions. Even when grouped within the broad categories of left, right and nonlateral, an increase in frequency in one category may be associated with a decrease in the frequency in either of the other categories. For example, in the Tucker, Antes, Stenslie and Barnhardt (1978) study, high anxious subjects made fewer left movements than low anxious ones, but did not make more right movements. Expressing such data as a ratio measure would have masked the complexity of the finding. The present results for both the frequency and extent measures argue strongly that left and right eye movements are different phenomenon, are influenced by different factors in the interaction between attention and the visual field, and should not be assumed to be perfect mirror images of each other.

There are some factors in the design of this experiment that may account for the lack of significant effects of question type on left LEMs. One variable is related to the nature of the spatial questions. Several researchers have pointed to the difficulty of developing spatial questions that retain predominantly spatial, rather than verbal, aspects (Arneson, note 3; Ehrlichman & Weinberger 1978; Galin & Ornstein 1974). In particular, they have indicated that when constructing a spatial question set, phrases which tend to induce a verbal or quantitative set should be avoided (e.g., "How many...," "Tell me..."). A special effort was made in this study to follow these spatial question construction guidelines. Perhaps an independent validation of the ability of both the spatial and the verbal question sets to selectively activate the left and right hemispheres, respectively, would have

addressed this issue. However, the few studies in which such a validation procedure was utilized (cf., Berg & Harris 1980; Hiscock 1977a) have failed to demonstrate question effects in the predicted directions for right or left LEMs.

A second factor that may have compromised the spatial question effects on left LEMs is the potential impact of having the subjects make a verbal response (left hemisphere task) to spatial questions (purportedly right hemisphere tasks). However, Berlucchi, Brizzolara, Marzi, Rizzolati, and Umilta (1979) have summarized a number of studies in which right hemisphere specialization for a visuo-spatial task has been demonstrated even when a verbal response is required. Consequently, the fact that subjects were required to respond verbally to the spatial question set is not necessary to account for the nonsignificant effect of spatial question on left LEMs.

Effect of Experimental Condition

According to the VHF SD theory, LEMs occur during reflective thought in order to selectively reduce interference from potentially distracting external stimuli. Thus, when compared to the number of LEMs made during a standard, eyes open condition (in which the subject views a symmetrical field while responding to reflective questions), fewer LEMs are expected to occur when visual distraction is reduced to a minimum (i.e., when the subject has his eyes closed). As predicted, significantly fewer right and left LEMs occurred during the eyes closed condition than during the standard, eyes open condition in this experiment. This finding contradicts Kinsbourne's (1972) proposal that LEMs result from an endogenous orientation

overflow mechanism that, because of its neurophysiological base, would be expected to operate similarly in either condition.

It is possible that the decrease of eye movements during the eyes closed condition resulted from factors not related to distraction reduction (i.e., muscular or other physiologically based ocular motility constraints). One way to control for these factors would be to have subjects engage in reflective thought in a completely darkened room, keeping their eyes open. The VHF SD theory would predict LEM frequencies during the dark room-eyes open condition to be similar to those during the eyes closed condition. A recent study has employed this darkened room paradigm to study LEMs (Säring & Von Cramon 1980). These authors asked subjects to respond to a series of verbal, numerical, and musical questions while reclining in a completely blackened room. The subjects were instructed to keep their eyes open throughout the procedure and their LEMs were recorded by EOG procedures. The results indicated that the percentage of trials in which no LEMs were made was larger than the percentage of trials when either left or right LEMs were made. Though no other experimental conditions were utilized to make a comparison with the darkened room LEM effects, Säring and Von Cramon's results provide support for the VHF SD prediction that reduced visual distraction decreases the number of LEMs.

To further examine the effects of distraction on the frequency of LEMs comparisons were made between the standard, eyes open condition and two conditions in which visual distractors were added to the subjects central visual field. If LEMs occur in response to distraction (as was suggested by the results described above), then the VHF SD theory predicts an increase in the number of LEMs to the right and

to the left because of the added potential of these distractors to interfere with reflective thought. The results of this study indicated that, as predicted, significantly more right LEMs occurred when either type of distractor stimuli (verbal, nonverbal) were present than during the standard, eyes open condition. Contrary to predictions, there was not a significant increase in left LEMs between the standard condition and either of the distractor conditions. Once again, the independence of the right and left eye movement phenomena is evident. Consequently, attempts to account for the differences between the effects of distraction on right and left LEMs are complicated.

Great care was taken to insure that the visual field facing the subjects was symmetrical and that communications from the experimenter were localized directly in front of them. More eye movements may have been produced because of the experimenter's instructions to "ignore" the visual distractors, yet this would not easily account for the selective increase in right, but not left, LEMs. How then can the different effects of distraction on right and left LEMs be understood?

One explanation might be that the specialized processing styles of the two cerebral hemispheres are differentially affected by the distracting stimuli. The left hemisphere has been shown to process information in sequential and analytical mode (cf., Nebes 1974), while the right hemisphere processes information in a synthetic and holistic mode (cf., Tucker 1976). The linear sequence of ideation in the left hemisphere may be difficult to maintain when broken by interruptions. In the right hemisphere, on the other hand, the greater degree of parallel processing may create a certain redundancy which is less susceptible

to distraction. Translated into LEMs, more right moves (left hemisphere) would be made to avoid the effects of distractors, while there would be smaller effects of distraction on left LEMs (right hemisphere).

A final prediction of the VHF SD theory concerning effects of distractors on LEM frequency is that the verbal/nonverbal distinctions of the distractor stimuli will differentially increase the number of LEMs to the right and to the left, respectively. Contrary to prediction, the number of right LEMs made during the verbal distraction condition were not significantly greater than during the nonverbal distraction condition, and, conversely, there was no difference in the number of left LEMs made during the nonverbal than during the verbal distraction condition. These results indicate that the two distractor sets were essentially acting equivalently rather than according to their specialized content. It is unclear why this occurred given that both the words and faces have consistently been shown to be lateralized stimuli (cf., Benton 1980; White 1969). It is possible that the subjects simply ignored the content of the distractors and categorized them more as "distractors in general." The ability of the verbal and nonverbal distractors to generate lateralized effects may have been enhanced if subjects had been required to more specifically attend to the distracting stimuli (cf., Hines & Smith 1977).

Interaction Effects

The VHF SD theory predicts additive effects of type of question and type of distractor condition on the number and direction of LEMs. That is, more right LEMs are hypothesized to occur to verbal questions when verbal distractors are also present, than during other question

type-experimental condition combinations. Similarly, more left LEMs are expected to occur during the spatial question-nonverbal distractor condition than during other combinations of question type-experimental conditions. The results of this study revealed non-significant interactions overall for both right and left LEMs.

More specific comparisons between various combinations of question type and experimental condition indicated that the only significant finding for the frequency of right or left LEMs was that more right LEMs occurred during the verbal question-verbal distraction condition than during any of the possible permutations of question type and non-distractor conditions. These significant effects could have been predicted given the previously described findings of significantly more rights to verbal questions and more rights to distraction conditions in general. Likewise, the absence of other significant interaction effects can also be traced to previously described findings. For example, the fact that verbal and spatial questions differentially effected the number of right LEMs, but not left LEM frequency, suggests that interaction effects might be plausible only when right LEMs are involved.

Although the lack of significant interaction effects can be easily attributed to the impact of the combined main effect results, it is also possible that the VHF SD hypothesis of additivity is inaccurate. Perhaps the addition of a lateralized stimulus (i.e., verbal, nonverbal distractors) to a lateralized cognitive task (i.e., verbal, spatial questions) has no predictable effects on the number or direction of LEMs. Research exploring similar phenomenon in perceptual lateralities have reported that once the left hemisphere, for example,

is selectively activated by one variable (e.g., a verbal task), the addition of a second activating factor (e.g., concurrent verbal memory task), does not produce increase right field advantage in tachistoscopically presented recognition tasks (Cohen 1975; Hellige 1978). Though these findings are not directly related to LEM research, they are certainly consistent with the results of the present study.

VHF SD Theory and Predictions Concerning Extent of LEMs

A unique dimension of both this study as well as the VHF SD theory is the examination of the effects of question type and/or the presence of visual distractors on the extent of LEMs made to the right or to the left.[4] The VHF SD theory assumes that LEM extension measures provide additional data concerning the distraction reducing functions of LEMs. That is, the greater the distraction in an individual's central visual field, the more extensive his LEMs in order to provide the greatest distance from the source of distraction. Thus, the minimal distraction (eyes closed) condition in this study is predicted to result in the least extensive LEMs and, conversely, the distractor conditions are predicted to generate the most extensive LEMs when compared with LEM extent during the standard condition.

The results indicate a perplexing mixture of both support and non-support for these predictions. For example, as predicted, less extensive right and left LEMs were made during the eyes closed condition than during the standard, eyes open condition. These findings parallel the pattern of results for frequency of LEMs in which fewer

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[4]Although the appropriateness of using extent measures has been alluded to in the LEM literature (Galin & Ornstein 1974), to this date, this measure has not been utilized.

eye movements occurred when visual distraction was at a minimum. Taken together, the decrease in frequency and extent of LEMs during the eyes closed condition reflects the functional significance of the LEM phenomenon (i.e., reduced distraction results in reduced "need" to divert gaze). Interestingly, neither extent nor frequency data of right or left LEMs during the eyes closed condition was differentially affected by cognitive content of reflective questions. That is, fewer, less extensive LEMs occurred during the eyes closed than during the standard, eyes open condition whether the reflective questions were verbal or spatial. These results are consistent with findings reported by Säring and Von Cramon (1980) in which no significant influence of question type on direction of LEMs was found in their eyes open-darkened room paradigm. Both Säring and Von Cramon's data and the present findings suggest that LEMs are specifically related to distraction but are not necessarily related to lateralized processing, at least in a situation in which distraction is minimized. Kinsbourne's (1972) proposal that eye movements occur because of an overflow of activation to an orientation system is once again contradicted. As described previously, if such an overflow mechanism is involved in LEMs, it would be expected to occur in both eyes closed and eyes open conditions and be related to lateralized reflective thinking.

When visual distractors are added to the standard, eyes open condition, the data demonstrate that, contrary to prediction, there is no significant increase in the average extent of right or left LEMs that occur (regardless of the verbal or nonverbal nature of the distractor). That is, addition of words or faces to the subject's central visual field did not differentially affect the size

of the initial LEM following question presentation. The difference in the results for the quantity (frequency) and the quality (extent) of LEMs in general, and right LEMs, in particular, was unexpected, but is perhaps understandable in retrospect. If, according to the VHF SD theory LEMs are made to avoid potentially distracting visual stimuli during reflective thinking, once the movement is made and the distracting stimuli are "out of range" (i.e., displaced from central field), the functional role of the LEM is accomplished. If distracting stimuli are simply added to the center of the central field (as was done in the present study) the size of the LEM does not necessarily "need" to increase. Perhaps an additional test of the effect of distraction on size of LEMs would be to alter the location of the distracting stimuli to the right or left of central field.

The VHF SD theory makes no specific predictions regarding question effects on LEM extent. That is, contrary to predictions regarding frequency data, there is no reason to assume that verbal or spatial questions should differentially affect the size of the LEMs per se. The nonsignificant results of the effects of question type on the LEM extent data are consistent with this assumption.

In view of the non-specific hypothesis about question effects on LEM extent, the interaction effects are predicted to reflect general trends that were evidenced in the hypothesized condition main effects (i.e., more extensive LEMs, regardless of question type, during distractor conditions than during the standard, eyes open condition). The interaction data for LEM extent was not significant for either left or right LEMs. However, a closer examination of the nonsignificant left LEM effects reflects a complicated pattern of results in

which larger left LEMs occur during the spatial question-type open condition and smaller left LEMs occur during the spatial question-eyes closed condition than during nearly all other question-condition combinations. On the other hand, a closer examination of the nonsignificant right LEM interaction effects for extent reveals a pattern of results that parallels previously reported trends in the condition effects for right movements. That is, regardless of question type, right eye movements occurring during the eyes closed condition are less extensive than those occurring in nearly all other question-condition combinations. The interaction effects on both right and left LEMs are difficult to explain. The LEM theories described thus far appear to be inadequate.

Nonlateral Trials

A striking feature of the results of this study is the large number (nearly 52%) of valid trials during which no apparent lateral eye movement was made. These nonlateral trials (NLT) reflect the tendency of the subject's eyes to remain on midline during reflective thought. Neither the VHF SD theory, nor the bilateral EOG recording of horizontal eye position utilized in the present experiment effectively addresses the NLT phenomenon. Consequently, specific predictions about the effects of question type and/or the presence of distraction on the number of NLTs cannot be made, nor can the nature of the NLT (i.e., whether they consist of vertical movements or stares) be directly examined. However, in view of the fact that the NLT phenomenon appears recurrently in the LEM literature (as reviewed by Ehrlichman & Weinberger 1978) and are so numerous in this study,

close examination of the NLT data within the expressed limitations was considered justified.

The results of the analyses of the NLT data reveal significant effects of both question type and experimental condition on the number of NLTs. Significantly fewer LEMs (more NLTs) were elicited to spatial than to verbal questions, and significantly more LEMs (fewer NLTs) occurred when the visual distractors were present than during non-distractor conditions. While the question type effects are consistent with other studies reporting NLT results (cf., Galin & Ornstein 1974), and the distractor effects are consistent with predictions made by the VHF SD theory, the inability of the methodology to more specifically distinguish between the type of NLT (up, down, stare) limits the range of interpretations than can be directly applied to this data. For example, Ehrlichman and Weinberger (1978) have contended that vertical movements and stares represent different aspects of NLTs. That is, vertical movements (up, down) have been shown to differentiate between verbal and spatial questions (more up to spatial, more down to verbal), while stares have consistently been associated with spatial question effects. Consequently, these authors criticize attempts to interpret NLTs as a unitary phenomenon. On the other hand, Galin and Ornstein (1974) have asserted that when NLTs occur, the effects are attributable primarily to stare responses because "pure" vertical movements occur infrequently. Thus, they have proposed that interpretations of NLTs should focus on understanding the stare response.

While there is no direct evidence in the present study that NLTs are primarily stare responses, EOG recordings in this study were such that NLTs were scored only when there was no evidence of a lateral shift

in the subject's valid eye movement responses. Thus, NLTs would consist of either "pure" vertical movements or stares. Given that pure vertical movements are infrequent (as cited above), it is reasonable to assume that most NLTs in this study were stares. Thus, interpretations of question and condition effects on NLTs (stares) can be proposed tentatively.

Two different interpretations have been suggested in the literature to explain the finding that more NLTs (stares) occurred to spatial than to verbal questions. Kinsbourne (1972) has proposed that staring reflects simultaneous (bilateral) activation of the cerebral hemispheres such that orientation is centered in the median plane. That is, since reflective questions and responses are verbal, both right and left hemispheres are activated by spatial questions and attention is directed centrally. This interpretation is challenged by previously cited research in which verbal responses had a nonsignificant effect on right hemisphere, visuo-spatial processing. Furthermore, Weiner and Ehrlichman (1976) have challenged Kinsbourne's model by presenting data which indicate that not only do more stares occur to spatial questions, but there is a general reduction in ocular motility (fewer subsequent eye movements). Additional support for this notion has been provided by studies in which eye movement density increased during left hemisphere activity (Cohen 1977) and decreased during right hemisphere, imagery tasks (Lavie & Kripke 1975). Weiner and Ehrlichman suggest that the stare response reflects a means of reducing the potentially distracting effects of external visual stimuli on the internal visuo-spatial processes. Similarly, Meskin and Singer (1974) have proposed that increased staring during spatial questions "gates" out external

visual stimulation in order to reduce interferences with an internally generated image.

These latter interpretations are consistent with the VHF SD's functional explanation for LEMs (i.e., that LEMs occur in order to reduce external distraction during reflective thought). It would appear that the NLT (stare) data could be easily integrated into the VHF SD theory. However, if stares are produced to reduce distraction, it would follow that the number of stares (NLTs) should increase as distraction increases. The data does not support this trend. Instead, it reveals that as distraction increases in the visual field, the number of NLTs decreases.

The large number of NLTs overall point to the possibility that methodological factors influenced the scoring of NLT responses. For example, instructions to maintain a focus while questions were being asked could have biased the subject's eye movement responses by increasing the tendency to remain "fixated" at the focus point momentarily following completion of the question. If this fixation lasted beyond the two second post question limit for scoring valid eye movements, it could easily be interpreted as a stare response. This focus induced fixation would be expected to occur less often during distraction conditions since the subjects were given specific instructions to ignore the distractor stimuli. The data are consistent with this possibility.

Summary and Implications for Future Eye Movement Research

This study was designed to examine a new theoretical approach for understanding the reflective lateral eye movement phenomenon. The basic tenet of this theory was that LEMs are a functional behavior that

provides a means by which an individual reduces distraction from external visual stimuli during reflective thought. Furthermore, the theory predicted that direction of gaze shift is contralateral to the hemisphere specialized for processing the cognitive content of reflective questions. The results offered an interesting and very complex array of evidence that supported some and failed to support others of the various theory-based predictions.

Support for the VHF SD theory came primarily from those findings in which the presence or absence of distracting stimuli differentially affected both frequency and extent measures of LEMs. However, the explanatory limitations of the model became clear when the findings indicated that right and left LEMs were affected differently by distractors. That is, more frequent right LEMs were made during distractor conditions than during nondistractor conditions, while extent of right LEMs did not vary between these conditions. Conversely, there was no difference in the number or the size of left LEMs made during distractor than nondistractor conditions. The VHF SD theory could only account for the frequency data of right LEMs but could not adequately address the apparent independence of right and left LEMs in response to distraction.

The occurrence of nonlateral trials posed another problem for the VHF SD theory. Although NLTs operated in theory-predicted ways to the presence or absence of distraction (i.e., fewer NLTs during distraction conditions), neither the theory nor the methodology was designed to account for the full range of possible NLTs (up, down, stare). Consequently, integration of NLTs into the VHF SD theory was inappropriate.

With regard to the theory's predictions of differential effects of cognitive content of questions and distractor stimuli on frequency measures, the results again were mixed. As predicted, more right movements occurred to verbal questions than to spatial questions. No question effect was evident for left LEMs. Also, contrary to prediction, the question type-distractor type effects were not additive to produce increases in LEMs to the right when both question and distractor were verbal, or more lefts when questions were spatial and distractors were nonverbal. Furthermore, the occurrence of more NLTs to spatial than to verbal questions was neither expected nor explained by the VHF SD theory. Thus, the theory's limitations in accounting for the impact of cognition on eye movement direction and frequency were clear.

Regardless of the theoretical and methodological limitations of the present experiment, the complexity of the results has important implications for future eye movement research. For example, the influence of distraction in the visual field during reflective thought appears to have very specific effects on eye movement behavior. Until this study, the influence of distractors had not been addressed directly in the LEM literature. Kinsbourne (1972) had suggested that asymmetry in the visual field or the presence of an interviewer facing the subject might influence a subject's need to divert his gaze, but he did not predict how these variables would affect direction, frequency, or extent of the eye movements. Subsequent research in which these variables have been examined has produced contradictory results (as reviewed in Ehrlichman & Weinberger 1978). It is clear that additional research is required to both replicate the results of the present study, as well as to extend the generalizability of distractor effects by exploring

different types of distractors (i.e., auditory, visual), in different locations, and of different intensities.

A second factor which emerged from the perplexing results of the present study is the necessity of considering all eye movement phenomenon as dependent variables in LEM research. It was obvious that both question type and experimental condition differentially affected right and left movements. A great deal of information about their occurrence would have been forfeited had data relevant to only one or the other been presented. Similarly, NLTs in this study replicated previous findings in the eye movement literature. Vertical responses and stares should be considered when attempting to understand eye movements in general. Research designs that relegate importance to only the lateral dimension of eye movements and make the assumption that right and left movements are simply mirror images perform a serious injustice in the complexity of the phenomenon.

Both frequency and extent of eye movements were utilized in this study and, unexpectedly, revealed contradictory information about the effects of the experimental manipulations on right and left LEMs. Interestingly, frequency measures of first eye movements occurring following question presentation have been prototypic throughout the majority of LEM studies, and have tended to reflect similar patterns of results as were demonstrated for number of right movements and NLTs in this study. However, measures of extent of first eye movements have not previously been employed and seem to provide unique information. Clearly, utilizing both measures has provided valuable information about the complexity of the phenomenon, and suggests the need for additional examination and speculation about the information that is being conveyed by different

measures of eye movements. For example, it is possible that frequency data reflects influences of internal cognitive factors as well as the influence of distraction on eye movement. On the other hand, measures of extent may be less influenced by internal cognition, but reveal something about the effects of distraction less related to attentional factors and more related to involvement of differential oculomotor cybernetics (i.e., differences in frequency of saccades).

One variable not addressed in the present study, though perhaps of interest for future research, is the effect of sex differences on eye movement behavior. There have been numerous reports in which various differences in lateralization between males and females have been identified (as reviewed in Levy 1980). However, the potential impact of these differences on lateralized task performance has received mixed reviews. The effects of sex differences as they relate specifically to the lateral eye movement phenomenon has received only limited attention in the LEM literature to date and has produced conflicting results (cf. Crouch 1976; Weiten & Etaugh 1974a). In view of the fact that sex differences have not been clearly or consistently delineated in LEM research, the generalizability of future LEM research will be enhanced if data for both male and female subjects are available for examination.

In summary, the VHF SD theory was shown to be inadequate to explain the complex array of results in the present study. The limitations of the model do not, in turn, limit the implications of its predicted effects of visual distraction on the reflective eye movement response. On the contrary, the role of distraction clearly surfaced as an important variable heretofore neglected in LEM research. The addition of this variable to an already impressive list of complex

concomitants of the eye movement response (e.g., task, subject, and personality variables as summarized in Ehrlichman & Weinberger 1978) could easily raise doubts about the value of the eye movement phenomenon as a viable research tool (cf. Corballis 1980). However, rather than detering additional research or theorizing, the complexity of the phenomenon provides numerous avenues of exploration and integration with such fields as cognition, information processing, personality styles, and interpersonal behavior.

This study provided additional pieces to the reflective eye movement puzzle. To discontinue attempts at further exploration of the puzzle simply because some other pieces do not fit runs the risk of a premature rejection of a potentially valuable research methodology. That is, to paraphrase Schlesinger (1980), although the domain of LEM research continues to be plagued with assumptions, inference, and questionable methodology, someday the value of the phenomenon will be supported (or refuted) in the "time honored scientific tradition of persistent and objective reasoning and experimentation" (p. 1147). The evidence from this and other studies investigating the reflective lateral eye movement phenomenon certainly makes the phenomenon worthy of pursuing further.

REFERENCE NOTES

APPENDICES

APPENDIX A

REFLECTIVE QUESTIONS

REFLECTIVE QUESTIONS

VERBAL

Set I

1. What is meant by the proverb? "The tongue is the enemy of the throat"?

2. Solve this problem: John is better than Phil, and Mike is worse than Phil. Who is worst?

3. What is the meaning of the word "strength"?

4. Make up a sentence using words "present" and "quest".

5. Explain: "He who lies on the ground cannot fall."

6. What word is the opposite of "assemble"?

7. Solve this problem: Margaret is taller than Sue, and Karen is shorter than Sue. Who is tallest?

8. What is the meaning of this common proverb: "A drowning man will clutch at a straw"?

9. What is the primary difference between the words "recognize" and "remember"?

10. What is the word that rhymes with "repair"?

Set II

1. What is the meaning of "shame"?

2. Explain: "It's better to have a good enemy than a bad friend."

3. Make up a sentence using "shock" and sadness".

4. Solve this problem: Al is smarter than Sam and Al is duller than Rick. Who is smartest?

5. What does this mean: "It is better to have a bad peace than a good war."

6. What is the primary difference between the meanings of the words "pride" and "vanity"?

7. What is a word that rhymes with "parade"?

8. Solve this problem: Jill is lighter than Ann and Jill is heavier than Marge. Who is lightest?

9. What is meant by the proverb "Strike while the iron is hot"?

10. What is the primary difference between the words "explain" and "define"?

Set III

1. Define "charity".

2. What does this proverb mean: "Rome was not built in a day"?

3. Make up a sentence using the words "code" and "mathematics".

4. What is the primary difference between the meanings of the words "flexible" and "reasonable"?

5. Explain: "A poor worker blames his tools."

6. Solve this problem: Mary is older than Sue and Sue is younger than Jane. Who is youngest?

7. Name the opposite of "reject".

8. In what ways are "mischief" and "malice" alike?

9. Briefly, explain the meaning of this common proverb: "Words should be weighed, not counted."

10. Solve this problem: Greg is worse than Joe and Steve is worse than Greg. Who is worst?

Set IV

1. What is a synonym for the word "enormous"?

2. Solve this problem: Jennie is better than Jane and Jane is better than Carol. Who is best?

3. What does this proverg mean: "If you can't bite, don't show your teeth"?

4. Define "economics".

5. Make up a sentence using the words "rhapsody" and "pleasure".

6. Explain: "The more cost, the more honor."

7. What word rhymes with winter?

8. Solve this problem: Mark runs faster than Bill and Mark runs slower than Jake. Who runs slowest?

9. In what ways are "praise" and "punishment" alike?

10. Briefly explain this common proverb: "All that glitters is not gold."

SPATIAL

Set I

1. If you draw a line from each of the upper two corners of a square to the midpoint of the bottom line of the square, what three figures result?

2. In the pictures of Napoleon, which hand does he hold in his coat?

3. If a person is facing the setting sun, where is north with respect to him/her?

4. Which city is closer to New York: Boston or Cleveland?

5. What is the color of the top stripe on the American flag?

6. A pentagon is a five sided figure. Are any two sides parallel to each other?

7. You are heading south and you make a left turn and then a right turn. In which direction are you now heading?

8. Where is Chicago relative to Grand Forks?

9. In which hand does the Statute of Liberty hold her torch?

10. When facing a circular telephone dial, which number appears furthest to the left?

Set II

1. In which direction does Abraham Lincoln face on a penny?

2. If a person is facing the rising sun, where is south with respect to him/her?

3. If you place two equilateral triangles side by side, what other standard geometric figures do you obtain?

4. On your Social Security card, where is your number relative to your name?

5. Which angle is greater: the smaller angle formed by the hands of a clock at 2:45 or the smaller angle formed by the hands of the clock at 2:30?

6. What is the color of the top stripe of the American flag?

7. If you were traveling from New York to San Francisco, which direction would you go?

8. When facing a soft drink vending machine, where is the money slot with respect to you?

9. Looking in the rear view mirror of a car at a car behind you, on which side does the driver appear to be sitting?

10. What direction is Indianapolis from Minneapolis?

Set III

1. A hexagon is a six sided figure. Are any two sides parallel?

2. Who looked more like John Kennedy--Bobby or Teddy?

3. In the painting "Whistler's Mother" is the woman facing to the left or to the right?

4. Which direction of the compass does the front of your house, apartment, or dorm face?

5. Which way does Jefferson face on a nickel?

6. If you are the minister at a wedding, on which side of you does the bride stand?

7. You are heading north, you make two right turns, and then a left turn. In which direction are you now heading?

8. What is the color of the bottom stripe of the American flag?

9. On your student I.D., where is your name relative to your student number?

10. What direction is Las Vegas from Dallas?

Set IV

1. When facing the TV you watch most often, where is the volume control relative to the screen?

2. If you are standing with your back to the right side of a friend who is facing west, what direction are you facing?

3. If you cut a paper cylinder length-wise and then lay it out flat, what shape is the resulting figure?

4. Which angle is greater: the smaller angle formed by the hands of a clock at ten after eleven or the smaller angle formed by the hands of a clock at twenty after eight?

5. Assuming University Avenue runs due east, in what direction does the Education Building face?

6. When facing a traffic "Yield" sign, in which direction does the triangle point?

7. What two figures do you have when you divide a rectangle in half by drawing a line from the upper left hand corner to the lower right?

8. On the dollar bill, does George Washington's face look to the right or to the left?

9. Which states would you pass through when traveling from Minneapolis?

10. When looking at a globe, what are two cities that are on opposite sides of the earth from each other?

APPENDIX B

NEUTRAL QUESTIONS

NEUTRAL QUESTIONS

1. What is your favorite food?

2. If you could change one thing about this University, what would it be?

3. If you could be any living person, who would you be?

4. What do you think is our country's greatest natural resource?

5. What qualities do you think most people seek in prospective friends?

APPENDIX C

VERBAL DISTRACTORS

VERBAL DISTRACTORS

NAIL	LION	DISH	AREA	TALE
CARD	CAST	ACRE	FLAT	ROPE
WAGE	SAND	DESK	CARD	HARM
MASS	PILE	SALE	CROP	FIRM
TONE	FAME	TEST	LAMP	BELL
WOOL	DAWN	REAR	RUIN	MEAL
MILL	TASK	FLAG	TEAM	FEED
LOCK	LOAD	DEPT	RANK	DECK
TERM	FOLD	HUNT	CORN	VEIN
BORE	WINE	PINK	BOND	BOWL
DEED	COPY	COIN	SAKE	POEM
WOLF	HERO	NOON	TENT	TALE
SILK	CALM	HORN	FARE	SEED
BARK	WIRE	AUNT	MAIL	BAND
PORT	BAKE	DUST	NEST	LIST

APPENDIX D

NONVERBAL DISTRACTORS

APPENDIX E

CROVITZ-ZENER HANDEDNESS QUESTIONNAIRE

CROVITZ-ZENER HANDEDNESS QUESTIONNAIRE

Answer the following questions carefully. Imagine yourself performing the activity described before answering each question. Answer by drawing a circle around the appropriate set of letters appearing to the left of each question whose meanings is:

Ra = right hand always	La = left hand always
Rm = right hand most of the time	Lm = left hand most of the time
E = both hands equally often	X = do not know which hand

(1)	Ra	Rm	E	Lm	La	X	:	is used to write with.
(2)	Ra	Rm	E	Lm		X	:	to hold nail when hammering.
(3)	Ra	Rm	E	Lm	La	X	:	to throw a ball.
(4)	Ra	Rm	E	Lm	La	X	:	to hold bottle when removing top.
(5)	Ra	Rm	E	Lm	La	X	:	is used to draw with.
(6)	Ra	Rm	E	Lm	La	X	:	to hold potato when peeling.
(7)	Ra	Rm	E	Lm	La	X	:	to hold pitcher when pouring out of it.
(8)	Ra	Rm	E	Lm	La	X	:	to hold scissors when cutting.
(9)	Ra	Rm	E	Lm	La	X	:	to hold knife when cutting food.
(10)	Ra	Rm	E	Lm	La	X	:	to hold needle when threading.
(11)	Ra	Rm	E	Lm	La	X	:	to hold drinking glass when drinking.
(12)	Ra	Rm	E	Lm	La	X	:	to hold tooth brush when brushing teeth.
(13)	Ra	Rm	E	Lm	La	X	:	to hold dish when wiping.
(14)	Ra	Rm	E	Lm	La	X	:	holds tennis racket when playing.

APPENDIX F

EXPERIMENTAL FEEDBACK QUESTIONNAIRE

EXPERIMENTAL FEEDBACK QUESTIONNAIRE

NAME______________________________ COURSE________________

EXPERIMENT NUMBER____________________ INSTRUCTOR______________

NAME OF EXPERIMENTER__________________ SEMESTER_______ YEAR______

1. Did the researcher show up on time?

2. Were your instructions adequately explained?

3. Did the researcher show willingness to answer questions?

4. Were you comfortable throughout the experiment? If not, what part(s) made you uncomfortable?

5. What is your understanding of what was being studied in this experiment?

6. Did you at any time feel that the experimenter was studying something other than what she told you? If so, what do you think was the real purpose of this experiment?

7. General Comments.

8. Would you participate in another psychology experiment?

9. If you would like some feedback concerning this experiment, please leave your address in the space below.

APPENDIX G

POST EXPERIMENTAL COMMENTS

POST EXPERIMENTAL COMMENTS

Some comments made by the subjects in this experiment regarding various aspects of the study:

(1) With regards to the eyes closed condition:

(a) Difficult to "focus" while the question was being read	(N=22)
(b) Tended to look down during this condition	(N=2)
(c) Felt my eyes drifting	(N=6)
(d) It was easier to respond to the questions when my eyes were closed	(N=1)
(e) Tended to look up during this condition	(N=1)

(2) With regards to the distractor conditions:

(a) Neither faces or words were distracting	
-- I looked "thru" the stimuli; ignored them	(N=15)
-- I just looked away	(N=4)
(b) Both faces and words were distracting	
-- I looked down	(N=3)
-- I closed my eyes	(N=5)
-- I looked away	(N=6)
-- They were only distracting when the questions were complicated	(N=2)
(c) Faces were more distracting than words	(N=9)
(d) Words were more distracting than faces	(N=4)

(3) Other Comments

It was hard to think when I had to focus on the dote while you were asking the question (N=1)

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