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The Relationship of Lateral Eye Movements to Field-Dependence-Independence and Verbal and Performance Skills

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The Relationship of Lateral Eye Movements to Field-Dependence-Independence and Verbal and Performance Skills

(TITLE)

BY

Linda J. Stennett-Mason

THESIS

SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS
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IN THE GRADUATE SCHOOL, EASTERN ILLINOIS UNIVERSITY
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THE RELATIONSHIP OF LATERAL EYE MOVEMENTS TO FIELD-DEPENDENCE-INDEPENDENCE AND VERBAL AND PERFORMANCE SKILLS

BY

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ABSTRACT OF A THESIS

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ABSTRACT

Lateral eye movements and handedness as indexes of hemisphere asymmetry were compared to field-dependence-independence, as measured by Rod-and-Frame Test errors, and to Wechsler Verbal and Performance IQs. Consistent with previous research, the hypotheses predicted that persons with inconsistent lateral eye movements (ambilaterality) would have greater Rod-and-Frame errors (field-dependence) and lower Wechsler Verbal and Performance IQs.

Subjects were 41 male undergraduates who were grouped according to their lateral eye movements in response to 20 reflective questions consisting of ten verbal (left-hemisphere) and ten spatial (right-hemisphere) questions. The response scoring resulted in 12 subjects with 70% or more lateral eye movements to the right who were classified as "right-movers" (left hemisphere dominant), 12 subjects with 70% or more lateral eye movements to the left who were classified as "left-movers" (right hemisphere dominant), and 17 subjects with inconsistent lateral eye movements who were classified as "bidirectionals" (ambilateral). Ambilaterals are assumed to have verbal functions equally represented in both hemispheres of the brain rather than left hemisphere specialization for that function. In addition to the subsequent administration of the handedness questionnaire, Rod-and-Frame Test, and the Wechsler, the existence of immediate or extended-family sinistrality (left-handedness) was also questioned.

Statistical analysis by means of one-way analysis of variance, stepwise regression, and discriminant analysis yielded no significant differences between the three groups on measures of LEMs, handedness, Verbal IQ,

Performance IQ, or Full Scale IQ. Chi square analysis of absence or presence of immediate or extended family sinistrality likewise yielded no significant results.

Introduction

Cerebral dominance has long been a topic of interest in research, especially with reference to its relation to language. As long ago as 1865, Broca associated left-handedness with cerebral representation of language in the right hemisphere (Hecaen & Sauguet, 1971).

The last decade has seen a resurgence of interest in hemispheric asymmetry. Ehrlichman and Weinberger (1978) propose two primary reasons for this renewed interest. The first is the discovery that each hemisphere has areas of specialization in function. This has been demonstrated in studies with patients with damage to one hemisphere or the other, and also in studies with commissurotomy patients following the complete surgical division of their forebrain commissures, which serve as cross-connecters in the coordination of higher mental functions between the two cerebral hemispheres. The second reason is the development of techniques for observing the effects of hemispheric asymmetry in normal people with intact brains.

With regard to hemispheric specialization, the commissurotomy patient has been especially helpful because the two cerebral hemispheres are relatively intact and available for separate testing, allowing comparison of the two sides of the brain on a given level within a single person. It is generally agreed from studies of cerebral disconnections that in the typical right-handed person, the left hemisphere is particularly specialized for an analytic, logical cognitive mode. Language processes, e.g. speech and writing, and arithmetic calculations are also primarily dependent upon the left hemisphere.

The right hemisphere is specialized for a holistic, gestalt mode, which is particularly suitable for some musical functions as well as spatial relations. The right hemisphere uses a nonverbal mode of representation, presumably images, and reasons by a nonlinear mode of association rather than by syllogistic logic. It is superior to the left in part-whole relations, and is less involved with perception of time and sequence than the left hemisphere (Nebes, 1974; Galin, 1974).

Left-handed individuals are indicated as having a different cortical organization (Annett, 1964; Levy, 1969; Hecaen & Sauguet, 1971). Generally, these results indicate a certain cerebral ambilaterality in left-handed subjects, particularly those with a family history of sinistrality (left-handedness).

Various laterality measures have been utilized to assess hemispheric asymmetry in normals. The traditional index of hemispheric specialization has been hand preference, as demonstrated by the earlier reference to Broca's 1865 formulations. Two other laterality measures have been ear asymmetry in dichotic listening tasks (Heilman et al., 1977) and lateral asymmetries in visual perception - more specifically, tachistoscopic half-field studies (Pirozzolo, 1977). These measures attempt to demonstrate a relationship between lateral sensory input and the hemisphere postulated to be dominant for the task.

Satz (1977) addressed some increasing abuses in the interpretation of these lateral sensory asymmetries. He challenged assumptions of hemispheric dominance based on a relationship between two variables such as ear asymmetry and speech-brain lateralization as reckless and

unwarranted. The need for more cautious inferences had earlier been demonstrated with respect to manual preferences by Goodglass and Quadfasel (1954) who, in a study of left-handed aphasics, found that the lesions which determine language difficulties might be in either hemisphere but were more often in the left. In effect, the study of left-handed aphasics showed that hemisphere dominance is not, as in right-handers, of a uniform type. Goodglass and Quadfasel concluded that it is incorrect to establish a direct relationship between manual preference and cerebral lateralization of language function because right cerebral dominance is much less frequent than left-handedness and because left cerebral dominance is more general than right-handedness.

The incongruities among hand, ear, and eye preferences have been interpreted by some researchers as indicative of incomplete cerebral lateralization, as mentioned previously. Crinella, Beck, and Robinson (1971) have concluded that evidence linking these aspects of unilateral consistency to brain organization is weak. However, Weiten and Etaugh (1974) have suggested that "another aspect of human laterality, lateral eye-movement, may be more intimately related to the functional organization of the brain and to intellectual performance than is unilateral preference" (p. 1203).

"Lateral eye movements" refer to the shifts in gaze to the right or left that occur when people engage in reflective thinking. Eye movements to the left or right have been hypothesized to reflect activation of the cerebral hemisphere contralateral to the direction

of gaze. This hypothesis has been tested by comparing the direction of lateral eye movements (LEMs) following questions designed to engage either the left or the right hemisphere.

Bakan (1969), in a study of hypnotic susceptibility, first proposed that LEMs might be an index of hemispheric asymmetry:

> The relationship between laterality of eye-movements, hypnotizability, and the other variables described above can be considered in terms of functional asymmetry of the brain. The right or left eye-movements which are the subject of this paper are controlled contralaterally by activity in Brodman's area 8, the frontal eye fields (Robinson, 1968). 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 eye movement (p. 790).

The importance of Bakan's proposal was that it offered a way to observe hemispheric asymmetries in normal persons through an external and highly visible indicator (Ehrlichman & Weinberger, 1978). Subsequent studies elaborated upon Bakan's hypothesis by suggesting that if LEMs reflected hemispheric asymmetry, then LEMs would be affected by the type of questions subjects had to answer (Kinsbourne, 1972; Kocel et al., 1972). Gur (1975) further refined the hypothesis in his findings that right-handers moved their eyes leftward when solving spatial problems and rightward for verbal problems when the questioner sat behind them; when facing the questioner, however, the same subjects

moved their eyes predominantly in only one direction, either right or left, regardless of the problem type. Gur concluded that cerebral hemispheres, though specialized for problem type, are also preferentially activated within the same individuals. The effect of the face-to-face situation was explained as being sufficiently anxiety-provoking to force the subject back upon characteristic and preferred modes of response.

In a critical review of lateral eye movements as indicators of hemispheric activation, Ehrlichman and Weinberger (1978) describe evidence from these studies as equivocal. The primary criticisms leveled against these studies are with reference to methodological ambiguities in the questions, scoring, and experimental situations which make interpretation difficult. While studies which attempt to correlate question type with hemisphere activation have yielded inconclusive results, these authors concede that studies of individual differences in LEM patterns have "indicated a fair degree of stability and some consistency in their correlates" (p. 1808). They point out, however, that the correlates have not been clearly related to hemispheric asymmetry. They conclude that further research is required before inferences about hemispheric function can be legitimately drawn from studies of lateral eye movements.

An obvious way of linking LEMs to hemisphere asymmetry in a normal population sample is to study LEMs in relation to some known function of the left or right hemisphere. This has been attempted in recent years with field-dependence-independence.

The field-dependence-independence dimension is defined as a continuum of individual differences in characteristic ways of processing information (Zoccolotti & Oltman, 1978). Field-dependence is measured by a variety of tests, but most commonly the Rod-and-Frame Test. The subject sits facing a rod surrounded by a tilted frame and is asked to adjust the rod to the true vertical position. Field-independent observers, presumably relying more on internal referents, sit the rod close to the vertical, while field-dependent observers tend to be influenced by the tilted external framework in their judgments of rod position (Galin, 1974).

Field-dependence, as measured by the Rod-and-Frame Test, has been correlated with a wide array of other characteristics of personality and performance. Considering the psychophysiological differences between extreme field-dependent and independent persons, Silverman (1969) speculated that extreme field-dependence might signify a subclinical cerebral injury.

In a follow-up on the Silverman speculation, Berent and Silverman (1973) administered verbal and visual paired-associate tasks to field-dependent college students. These tasks had earlier been used by Starck (1961) to discriminate successfully between patients with known brain damage localized in either the left or right cerebral hemisphere. Starck had found that right-hemisphere patients performed poorly on the forms but not the words task, and the reverse was true for left-hemisphere patients. Corresponding to the findings of Starck (1961), Berent and Silverman found that field-dependent subjects showed a relative deficiency on the words section, suggesting a relative deficit in left hemisphere

functioning.

In order to directly test the relation between lateralized cerebral dysfunction and field-dependent performance on the rod and frame test, Cohen, Berent, and Silverman (1973) then studied a group of right-handed depressed female patients who were undergoing a single ECT administered either to the right or left cerebral hemisphere. They hypothesized that if field-dependence is related to left-hemisphere dysfunction, then left-hemisphere ECT patients should have increased rod-and-frame error scores. Supporting their hypothesis, they found that all 12 left-ECT patients did indeed show greater field-dependence on the posttreatment test. An unexpected result was that all 12 patients who had right ECT showed less field-dependence. Thus, field-dependence was inferred as being associated with a relative right hemisphere dominance, rather than a left hemisphere dysfunction.

More recently, Zoccolotti and Oltman (1978) have qualified this inference. They point out studies which have linked the degree of field-dependence to the extent of cerebral lateralization. For example, right-handers have been shown to be more field-independent and to have greater cerebral asymmetry (Silverman, Adevai, & McGough, 1966; Pizzamiglio, 1974). However, these studies are relevant only to the degree of left-hemisphere dominance for verbal functions. Zoccolotti and Oltman (1978) provided evidence which links field-dependence-independence to lateralization of the right hemisphere as well. Using only right-handed male subjects, they tested the hypothesis that field-independent subjects would show both greater left hemisphere specialization for verbal

processing and greater right hemisphere specialization for configural processing than will field-dependent subjects. Verbal and face stimuli were tachistoscopically presented to subjects in separate series in the left, center, and right visual fields. A second experiment included a letter-discrimination task. The results were consistent with the hypothesis that field-independents would show opposite lateral superiorities for verbal and configural material to a greater extent than field-dependents. The field-dependence-independence dimension was concluded to be related to the degree of segregation of functioning between the two hemispheres, rather than to some generalized tendency to use one or the other. Results were interpreted as indicating a link between Witkin et al.'s (1974) concept of psychological differentiation and differentiation of the neural level manifested by specialization of function of the cerebral hemispheres.

Several studies have employed lateral eye movements to measure the relationship between lateral asymmetry and field-dependence. In one such study involving three separate experiments, Ehrlichman (1977) found a small relationship between field-dependent cognitive style and the tendency to give a higher percentage of right lateral eye movements to verbal than to spatial questions. However, only one of these experiments was significant and it was concluded that sample differences on the field-dependence-independence dimension could probably not account for different patterns of results in studies of lateral eye movements.

Another study by Hoffman and Kagan (1977) found more positive results. Eighty right-handed undergraduates were administered the Portable Rod-and-

Frame Test, the Embedded Figures Test, and the Block Design, Object Assembly, and Picture Completion scales of the WAIS. Eye movements in response to questions requiring reflective thought were recorded. Contrary to the experimenters' predictions, right-movers were not found to be more field-independent than left-movers. Among males, however, both consistent right- and left-movers performed significantly better than inconsistent movers.

These results supported an earlier hypothesis by Weiten and Etaugh (1974) that the consistency of eye movement direction is related to the degree of brain lateralization, i.e. the extent to which the hemispheres are functionally segregated. This also represents a natural extention of Bakan's (1969) hypothesis relating eye movement directionality to preferred cognitive mode. The additional assumption is that some individuals have analytic and global modes equally represented in each hemisphere, while others have a strong preference for one cognitive mode over the other. According to Hoffman and Kagan (1977), the individual who is relatively more lateralized will more consistently engage one or the other hemisphere and hence avert his gaze consistently to one or the other direction. The idea of individual differences in degree of lateralization is also consistent with the earlier-stated conclusions by Zoccolotti and Oltman (1978).

Considering the interpretation of a "preferred" cognitive mode and eye-movement consistency raises the question of whether consistent movers have greater analytic ability than inconsistent movers. Hoffman and Kagan (1977) propose that lateral eye movement consistency and cognitive ability level are both functions of the extent of brain

lateralization, at least for males. They cite several studies which support this model through examination of eye-movement consistency in relation to other variables. For example, Weiten and Etaugh (1974) found that consistent movers had higher SAT scores than inconsistent movers. Croghan and Bullard (1975) found that inconsistent females took longer on a series of arithmetic problems than did consistent females. Despite this latter study, there is less evidence to support the relation between eye movement consistency and analytic ability for females. Hoffman and Kagan (1977) speculate on two possible explanations for this phenomenon: (1) Cerebral lateralization may not be related to intellectual performance in the same way for females as for males, and (2) Eye movement may not be as sensitive an indicator of hemispheric organization and/or functioning for females as for males. The latter explanation was supported by Gur and Gur (1974), who found no relation between eye-movement direction and hypnotizability for right-handed females, whereas correlations for males were sizeable and significant. However, contrary evidence was provided in a later study by Dewitt and Averill (1976), who found in 48 female subjects, that left-gazing (right hemisphere activity) was positively related to field-dependence and also to hypnotic susceptibility.

Incomplete cerebral lateralization has been implicated at one time or another in a variety of intellectual disorders, from dyslexia to extreme field-dependence (Hoffman & Kagan, 1977). This is not inconsistent with evidence indicating that hemispheric specialization, in most cases, increases with age. More specifically, Lennenberg (1967) stated that left hemisphere specialization for language occurs between ages

three and five and increases thereafter, with the right hemisphere gradually performing less of the language functions until puberty when the adult degree of dominance by the left hemisphere is permanently established (Geffen, 1976). Geffen explored this idea further by studying the right ear advantage in a dichotic monitoring task to three groups of right-handed subjects, aged five, seven, and eleven years. She found a right ear advantage, the magnitude of which did not change with age, and concluded that at five years of age, the left hemisphere is specialized for the analysis of speech signals.

This conclusion is of a general nature, however, and does not provide insight into the specific language advantages which the left hemisphere reportedly has. Using a hemisphere specialization of function paradigm to test cognitive skill and cognitive style in learning disabled and normal boys between the ages of seven and twelve, Guyer and Friedman (1975) concluded that language development is not a unitary factor. For example, the boys with a two year lag in reading comprehension showed no evidence of deficiency in short-term verbal memory and verbal concepts. However, they were found to be more field-dependent. Since the Rod-and-Frame Test is a test of cognitive differentiation, the authors speculated that perhaps it is verbal differentiation and prediction that is necessary for verbal and thus reading comprehension. More specifically, the authors state, "if a child did not differentiate well between words that have similar meanings, his organization of them in memory would be global and access to a precise word would be difficult" (p. 666). As an aside, the authors reasoned that when a field-sensitive child interacts with a field-

independent teacher, the student may not comprehend the teacher's instructions, possibly because of lack of verbal differentiation and possibly because the instructions are inappropriate for the cognitive style in which he functions best. They further suggest the need to draw on current knowledge of the nonverbal representational systems to aid in developing verbal representational systems.

Sadick and Ginsburg (1978) cite several studies which have indicated that poor reading ability and learning difficulties in children, within the normal ranges of variability, are correlated with ambilaterality. Ambilaterality is defined as "that state in which cerebral representation for the lateral functions associated with speech is equally divided between the two hemispheres" (p. 3). They attempted to elucidate the relationship between reading ability and language lateralization, as indicated by ear advantage on dichotic listening, by comparing the magnitude of ear asymmetry with reading achievement in seven year olds and also in a population of children from five to eleven years. The resultant data indicated that the progression of laterality appears to be from little asymmetry (ambilaterality) in the earliest learning-to-read stages (at five, six, and seven) when both sides of the brain are necessary for the vast amount of visual-spatial as well as linguistic material to be processed, to a maximum asymmetry in the later, fluent reading stage (eight and older) when the language side of the brain, usually the left, appears to be specialized for this skill. Concurrent with previous studies, the authors conclude that hemispheric asymmetry is advantageous to reading ability.

In addition to the findings that ambilaterality, or lack of asymmetry, is detrimental to reading ability, it has also been shown as disadvantageous to the spatial functions of the right hemisphere. Using handedness as an index of lateralization, Levy (1969) suggested that left-handed persons have their verbal functions represented in both hemispheres of the brain, while right-handers have their verbal functions confined to the left hemisphere. She argued that verbal functions undertaken by the right hemisphere in the left-hander would be at the expense of the spatial functions usually subserved by that hemisphere. Comparing verbal and performance scales of the WAIS given to ten left-handed and 15 right-handed graduate students, her hypothesis that people with partial language competency in both hemispheres would perform relatively poorly on tests of perceptual function, was supported. Contrary to conclusions by Sadick and Ginsburg (1978), Levy found no differences between groups on Verbal IQ.

Annett (1964) proposed a model of handedness and cerebral dominance with a genetic basis. Annett first qualified that "left-handedness" usually refers to the more numerous mixed-handers who have speech mediated by both hemispheres. The pure left-handed, right-hemisphere dominant person is relatively rare. Annett suggested that visuo-spatial skills are biologically more primary and that "given one intact hemisphere and the alternative of using it for either speech or visuo-spatial functions, speech would be allowed to suffer" (p. 60). Thus, Annett's theory would predict the opposite of Levy's: that mixed-handers (left-handers) would be impaired verbally but similar to the right-handers in visuo-spatial processing. This is more consistent with the conclusion of Sadick and Ginsburg (1978)

that verbal impairment, e.g., poor reading ability, is related to ambilaterality.

Levy's model is adopted by Sherman, Kulhavy, and Burns (1976), who suggest that in right-handedness, both hemispheres are highly specialized for a particular mode of processing and lateralization is complete, whereas in left-handedness, the lateralization of function is most often incomplete. To further investigate the functional specialization of the dual-processing systems, these experimenters had right- and left-handed subjects learn lists of abstract and concrete words under various conditions of visual and tactile interference. The hypothesis was consistent with Levy's model in predicting that right-handed and left-handed groups would not differ on purely verbal tasks (abstract), whereas left-handers would be impaired on visuo-spatial processing (concrete). Providing firm support for Levy's model, the experimenters found that right-handed subjects showed a significant superiority in the remembering of highly concrete items (visuo-spatial processing).

As well as providing disconfirming evidence for Annett's theory, these results may also be contradictory to an earlier suggestion by Newcombe and Ratcliff (1973) that non-right handers with a family history of sinistrality have language represented in the left hemisphere rather than ambilaterally, and thus have no verbal or performance deficits; however, Sherman et al. (1976) do not distinguish between those of their subjects with and without a family history of sinistrality.

A study by Briggs, Nebes, and Kinsbourne (1976) comparing the scores of right-, mixed-, and left-handers on the WAIS showed that left and mixed-handers had a significantly lower Full-Scale IQ than right-handers;

and, in all three groups, subjects with a positive family history of sinistrality had a lower Full-Scale IQ. However, neither handedness nor family history of sinistrality differentially affected the Verbal or Performance subscales. Rather than the degree of lateralization being the vital factor, these data suggest that any substantial variation from the right-handed pattern is, according to authors, associated with a significantly lower Full-Scale IQ.

From the diverse results of studies reviewed, it thus appears that the potential for the development of language in either hemisphere is available from birth, and that the potential decreases with age. However, the balance of language representation and the functional results of that balance are still relatively unclear.

The present study attempted to elucidate the relationship between the degree of lateralization, field-dependence, and cognitive ability by using both lateral eye movements and handedness as indicators of the degree of lateralization. The study was restricted to male subjects for four reasons: (1) There is more consistent evidence to suggest that lateral eye movements are indicators of hemispheric organization and/or functioning in males than in females (Hoffman & Kagan, 1977; Gur & Gur, 1974); (2) Females have been shown to be more field-dependent than males (Witkin, Goodenough, & Karp); (3) Females have been shown to be inferior to males in spatial ability (Harris, 1975); and (4) Since the relationship between the stated variables is inconclusive, a more homogeneous group would make the results less ambiguous.

Three hypotheses were proposed for this study. First, since the

field-dependence-independence dimension is reportedly associated with the degree of segregation of functioning between the two hemispheres (Zoccolotti & Oltman, 1978), and since the consistency of eye movement direction is related to the degree of brain lateralization (Weiten & Etaugh, 1974), it was hypothesized that subjects with inconsistent lateral eye movements (bilaterals) would make a significantly higher number of errors on the Rod-and-Frame Test, indicating greater field-dependence, than either left or right-consistent movers.

The second hypothesis was that inconsistent movers would also score significantly lower on both Verbal and Performance scales of the WAIS than either left or right-consistent movers, since a lack of asymmetry has been found detrimental to verbal skills, i.e. reading ability (Annett, 1964; Sadick & Ginsburg, 1978) and has also been shown to be at the expense of the performance skills, i.e. spatial functions, or the right hemisphere (Levy, 1969; Sherman et al., 1976).

Finally, it has been shown that lateral eye movement in response to questions is an index of hemisphere laterality and that an LEM to the left or right reflects activation of the contralateral hemisphere (Bakan, 1969; Weiten & Etaugh, 1974; Hoffman & Kagan, 1977). Three primary elements interplay to affect the direction and consistency of LEMs: (1) the type of question asked (Kinsbourne, 1972; Kocel et al., 1972); (2) the position of the questioner (Gur, 1975); and (3) individual preference or consistency of LEM pattern (Ehrlichman & Weinberger, 1978). The hypothesis which evolved from these findings and also from the conclusion that any substantial variation from the right-handed pattern is associated with

a significantly lower Full-Scale IQ (Briggs et al., 1976) is: given an equal number of verbal versus spatial questions and questioner-position facing subject, that subjects with LEMs consistently to the right would have significantly higher Full-Scale IQs than those with inconsistent eye movements (bilaterals) or those with lateral eye movements consistently to the left.

Method

Subjects

Subjects were 41 undergraduate males ranging in age from 18 to 31. The mean age of this group was 19.78 years and the standard deviation was 2.26 years. The subjects were recruited from four Introductory Psychology classes of Eastern Illinois University. The subjects from one class (N = 17) volunteered to participate in the study in lieu of completing a paper required for the course. The other 24 subjects were offered a nominal fee of $3.00 for participating. The subjects were majoring in several different areas, and the majority were not psychology majors.

Apparatus

Ten verbal and ten spatial questions designed to elicit reflective eye movements were compiled from previous studies. These questions are represented in Table 1. The 20 questions were randomly ordered, and were

---

Insert Table 1 about here

---

preceded by three questions which were intended to acclimate the subject to the experimental situation (What is your full name? What is your address? What is your birthdate?)

Hand dominance was measured by the Crovitz and Zener Test for Handedness (1962) with ratings from one to five for each of the 14 items. Two additional questions, requiring yes or no answers, were added to the

Table 1

Questions to Elicit Reflective Eye Movements

Verbal Questions	Spatial Questions
1. Define the word "economics."	1. Imagine a rectangle. Divide it in half by drawing a line from the upper left-hand corner to the lower right. What two figures do you now have?
2. Build a sentence using these 3 words: Failure, Business, Incompetent.	2. Try to picture all the doors in your house and tell me how many door knobs there are.
3. Solve the following arithmetic problem: 144/6 x 4.	3. How many edges are there on a cube?
4. Al is smarter than Sam and Al is duller than Rick - who is the smartest?	4. Which direction of the compass does the front of your house face?
5. Make up a sentence using two forms of the same verb.	5. Who looked more like John Kennedy - Teddy or Bobby?
6. How many letters are there in in the word "Anthropology?"	6. On the face of a quarter, does John Kennedy look to his right or to his left?
7. What is a word with three syllables?	7. If a person is facing the rising sun, where is south with respect to him?
8. Subtract 37 from 76.	8. Hum one stanza of "Row, Row, Row Your Boat."
9. Tell me an English word that starts with "L" and ends with "C".	9. With your eyes open, try to form an image in your mind of a man crying.
10. What is the first line of the Gettysburg Address?	10. What color was your very first bike?

handedness questionnaire to ascertain whether sinistrality was existent in the subjects' immediate or extended families.

The Portable Rod-and-Frame Test (Oltman, 1968) was employed as a measure of the field-dependence-independence dimension.

The Wechsler Adult Intelligence Scale (Wechsler, 1955) was employed to provide measures of verbal and nonverbal abilities. Three verbal subtests were used to provide a Verbal IQ: Comprehension, Similarities, and Vocabulary. Three performance subtests were used to provide a Performance IQ: Picture Completion, Block Design, and Object Assembly.

Procedure

Each subject was seen individually and administered the lateral eye movement questions, the handedness questionnaire, the Portable Rod-and-Frame Test, and the Wechsler Adult Intelligence Scale, in that order. Testing time ranged from 55 to 90 minutes, and the average session lasted approximately 75 minutes.

At the time of recruitment, subjects were told that the experiment was a study of "cognitive processing", with no mention of eye movements. Appointments were then scheduled at each subject's convenience.

Each subject appeared at his appointed time in the Perception Laboratory, which is a large room with tables in the center and closed cubicles running the length of the room on either side.

Subjects were first asked to sit facing the experimenter at a table in the center of the Perception Lab, where they were read the following instructions:

You are participating in a study on "cognitive processing." The first part of the study concerns the manner in which different people approach different types of questions. You will be asked 23 questions. The questions will not be repeated, so please listen carefully. Consider each question a moment before answering.

The direction of the first lateral eye movement following each question was scored even though lateral eye movements were sometimes made before the question was completely presented. Often subjects would momentarily look in one direction and then the other. These movements were also scored as eye movements in the direction of the initial glance. Scoring was done by the experimenter during the testing session. Each movement to the right was scored +1, each movement to the left was scored -1, and each movement up, down, or straight ahead with no lateral direction was scored 0. Subjects' answers to questions were not recorded.

While still seated, the subject was asked next to complete the handedness questionnaire, preceded by the following instructions which were read to the subject:

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. Write yes or no in response to the final two questions.

Each of the 14 items was later scored by examiner on a five-point

scale. The highest possible right-handed score was 14 and the highest left-handed score was 70.

Following administration of the handedness questionnaire, the subject was moved to one of the cubicles at the side of the room, where he was seated in a chair with his feet on a footrest and chin on the chin rest of the Rod-and-Frame device. The following instructions were read to the subject:

> When I open this curtain you will see a square frame and a rod which can be tilted. I want you to tell me which way to move the rod to make it vertical, that is gravitational or true vertical. When you believe the rod is true vertical say "stop." We will do this a number of times.

The rod was moved in 3^{o} increments until the subject stated the rod was in true vertical position, and the curtain was closed between the trials. According to the Oltman (1968) procedure, eight trials were given, and the subject's score was the average degrees of deviation from center position for the eight trials.

Finally, each subject was moved back to his original position in the center of the lab room for the administration of the six subtests of the WAIS. The three subtests for both verbal and performance sections were prorated to derive Verbal and Performance IQs.

Results

Similar to the procedure used by Bakan (1969) and Gur & Gur (1975), subjects were classified as left-movers if 70% or more of their eye movements were to the left, right-movers if 70% or more of their eye movements were to the right, and bidirectionals otherwise. Of the 41 subjects, 12 were classified as left-movers, 12 as right-movers, and 17 as bidirectionals. The means and standard deviations of each group's scores on handedness, rod and frame errors, Verbal IQ, Performance IQ, Full Scale IQ, and eye movement consistency are represented in Table 2.

Insert Table 2 about here

Using an SPSS (Nie, Hull, & Jenkins, 1975) program for one-way analysis of variance for unequal N's, F-ratios were computed between the variables of each group. The results of the one-way analysis of variance are represented in Table 3.

Insert Table 3 about here

The first hypothesis, that the bidirectional group would have significantly higher rod and frame error scores, was not supported. The bidirectionals did, in fact, have fewer errors than the other two groups, but there were no significant differences between the three groups: $F\ (2,38) = .1247$, N.S.

The Verbal IQs and Performance IQs were also contradictory to the

Table 2

Group Means and Standard Deviations

of Handedness, Rod & Frame Test Errors, Verbal IQ

Performance IQ, Full Scale IQ, and Lateral Eye Movements

Variable	Group		
	Right-movers (N = 12)	Bidirectionals (N = 17)	Left-movers (N = 12)
Handedness			
M	27.92	30.00	31.00
SD	7.97	11.73	14.93
Rod & Frame			
M	6.16	5.14	6.14
SD	6.08	5.90	7.27
Verbal IQ			
M	116.08	119.06	115.83
SD	9.64	10.31	11.75
Performance IQ			
M	112.67	116.94	110.33
SD	17.42	14.36	11.92
Full-Scale IQ			
M	115.58	119.47	114.50
SD	12.18	11.41	8.78
LEMs			
M	+132.50	- 10.00	-147.50
SD	37.20	68.74	30.79

Table 3

One-way Analysis of Variance

Variable	D.F.	Sum of Squares	Mean Squares	F Ratio
Handedness				
Between Groups	2	59.96	29.98	.2129
Within Groups	38	5350.92	140.81	
Total	40	5410.88		
Rod & Frame				
Between Groups	2	10.14	5.07	.1247
Within Groups	38	1544.51	40.65	
Total	40	1554.65		
Verbal IQ				
Between Groups	2	96.04	48.02	.4304
Within Groups	38	4239.52	111.56	
Total	40	4335.56		
Performance IQ				
Between Groups	2	327.29	163.64	.7583
Within Groups	38	8200.27	215.80	
Total	40	8527.56		
Full Scale IQ				
Between Groups	2	202.24	101.12	.8419
Within Groups	38	4564.15	120.11	
Total	40	4766.39		

predictions of the second hypothesis, that the bidirectional group would score significantly lower than either left or right-movers on Verbal and Performance tests. There were no significant differences between the three groups even though the Verbal and Performance IQs of the bidirectionals were higher than those of the left-movers or right-movers, VIQ: F (2,38) = .4304, N.S.; and PIQ: F (2,38) = .7583, N.S.

The third hypothesis, that the right-mover group would have superior Full-Scale IQs in comparison to the other two groups, was also unsupported. Bidirectionals were the group with the highest Full-Scale IQs, but the differences between the groups were not significant, FSIQ: F (2,38) = .8419, N.S.

Since the one-way analysis of variance yielded no significant results, a posteriori tests were employed to further analyze the data to determine if any significant differences or meaningful relationships existed. Using the sums of weighted scores for left and right eye movements as a continuous measure of eye movement consistency, a stepwise regression was performed to identify those predictor sets which would be optimally related to lateral eye movement. However, it was found that the variables did not predict group membership. As a multivariate method of determining group differences, a discriminant analysis was performed. Again, no significant differences were found between the groups.

One may conclude from the various methods of statistical analysis that, contrary to past research and the hypotheses of this study, variation between the groups on measures of Verbal IQ, Performance IQ,

Full Scale IQ, and rod and frame test scores was no greater than the random variation found within the groups on these measures.

The frequency of yes and no answers to immediate and extended family sinistrality questions for right-movers, bidirectionals, and left-movers is represented in Table 4. A chi square analysis of each 3 x 2 matrix did not yield significant results for immediate family sinistrality

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Insert Table 4 about here

(χ^2 (1,2) = .806, N.S.) or for extended family sinistrality (χ^2 (1,2) = .580, N.S.). The data thus lends no support for a relationship between family history (immediate or extended) of sinistrality and lateral eye movement consistency.

Discussion

Eye movement directionality, as an index of hemisphere laterality, was not found in the present investigation to significantly affect field dependence, intellectual verbal ability, or intellectual performance ability.

There are several possible explanations for the results of the current investigation. The first concerns the stimuli used to elicit reflective eye movement. The assumption that verbal questions (definitions, phonetic problems, arithmetic problems, and logical problems) would activate the left hemisphere and produce LEMs to the right, and that spatial, visualization, and musical questions would activate right hemisphere processes

Table 4

Immediate and Extended Family Sinistrality

Immediate Family Sinistrality

	Yes	No	
Right-movers (N = 12)	4	8	12
Bidirectionals (N = 17)	8	9	17
Left-movers (N = 12)	6	6	12
	18	23	

N = 41

Extended Family Sinistrality

	Yes	No	
Right-movers (N = 12)	7	5	12
Bidirectionals (N = 17)	12	5	17
Left-movers (N = 12)	8	4	12
	27	14	

N = 41

and produce LEMs to the left, may be open to question because there are no independent verifications that "left-hemisphere questions" do in fact engage the left hemisphere. This lack of verification was pointed out by Ehrlichman and Weinberger (1978), who reviewed 19 experiments which compared "left-hemisphere" questions with "right-hemisphere" questions. They report that of the 19, nine have found a significantly greater proportion of right LEMs for left-hemisphere questions, one found a greater proportion of right LEMs for right-hemisphere questions, and nine found no significant differences between left- and right-hemisphere questions. Therefore, evidence is inconclusive but not contrary to the assumption that hemisphere activation is related to question type. In the absence of such evidence, researchers have relied upon a form of face validity in which questions are chosen that conform to the investigator's conception of hemispheric specialization (Ehrlichman & Weinberger, 1978).

Given this apparent lack of construct validity, another contributing factor to the insignificant results of this study may have been poor quality of the eliciting questions. The fact that the same items have been used in both successful and unsuccessful past studies, however, makes the charge not a plausible one, except with regard to the two numerical questions which were used as left-hemisphere questions in this study. The hemisphere-activating properties of numerical questions is equivocal, so that some studies have used a separate and equal set of arithmetic questions to match verbal and spatial questions (Kinsbourne, 1972; Gur, Gur, & Harris, 1975; Gur, 1975) while others have used arithmetic questions as a kind of neutral stimulus whose effects "would not be sufficiently strong to mask individual differences in gazing behavior" (DeWitt & Averill, 1976, p. 1181). While the purpose of the present investigation was to determine

the function of asymmetry rather than hemisphere activation due to question type, the consideration of each question's hemisphere-activating properties is relevant in order to assure an equal representation of left- and right-hemisphere activating questions. For this reason, any follow-up study would probably eliminate the arithmetic questions as part of the verbal stimuli.

A second broad concern is with respect to scoring. This particular study scored responses according to the initial glance, even though the eyes may have immediately shifted to a different direction and maintained that gaze during reflection. Quickly averting the eyes from one direction to the other may comprise a sort of "searching" for the most suitable hemisphere to solve a particular problem. This idea is consistent with the "resolution by speed" hypothesis proposed by Galin (1974) which suggested that the hemisphere that solves the problem first, gets to the output channel first because it is intrinsically better equipped to handle some task. Thus, scoring the initial glance may have been scoring the "search" rather than indicating which hemisphere was ultimately activated for the particular question. The relationship of lateral eye movements to hemisphere activation/dominance is more complex than heretofore supposed.

Also along the line of scoring, and more specifically as applied to grouping, there are at least two researchers who contend that stares may "indicate bilateral activation" (Galin & Ornstein, 1974, p. 373). Although stares were scored 0 and figured into the consistency scores of this study, future studies may do well to give more careful consideration to high stare frequencies as an index of hemisphere symmetry.

A third major concern to this study is that reflective eye movements may not be valid or reliable indicators of hemisphere asymmetry. With regard to this question, Ehrlichman and Weinberger (1978) in a critical review of the research concede that, while there is inconsistent evidence that lateral eye movement is the result of hemisphere activation by a particular question type (as mentioned previously), there is more stable evidence that individuals have a directional mode which they consistently prefer. These reviewers challenge, however, that there is no persuasive evidence that hemisphere asymmetry does in fact account for such preferences.

At the conclusion of this study, the strength of the relationship between lateral eye movements and hemisphere asymmetry remains equivocal, emphasizing the need for additional studies which will determine with greater certainty how intimately the two are linked together. This author suggests that the question may be partially answered by a study with a time series design in order to test the reliability of a sample of subjects' preferred directionality modes in response to the same stimuli at different points in time. A further advance in this area would be to measure the lateral eye movements of commissurotomy patients, whose hemispheres are intact and available for separate testing. This type of investigation should provide more conclusive evidence for the link between hemisphere dominance and lateral eye movements.

A final explanation for this study's non-predictive value of eye-movement directionality may be that, contrary to studies previously cited, unilateral dominance is not truly related to neuropsychological integrity.

In concurrence with this idea, Crinella, Beck, and Robinson (1971) state the following:

> Comparative and developmental neuropsychological literature relating to the question of cerebral dominance and limb and eye preference suggest that there is no biological rationale for assuming that the two phenomena are related or that agreement in eye, hand, and foot preference or strength of lateral preference should confer an adaptive advantage on the human organism (p. 2033).

In order to test this statement, the authors (Crinella et al., 1971) compared 53 children who were behaviorally impaired secondary to verified or suspected central nervous system pathology with 37 who were above average in academic standing. No strong linear predictive relationships were established between lateral asymmetry, strength of lateral preference, and 70 neuropsychological test measures. The authors concluded that the strength of lateral asymmetry has limited significance for human behavior, and contend that the necessity for complementarity between the asymmetrically organized hemispheres is suggested as a more basic developmental necessity.

Also offering support for the value of hemisphere symmetry, Combs et al. (1977) propose the likelihood that subjects who utilize internal imagery (right hemisphere) may revert to the verbal cognitive mode (left hemisphere) to analyze the content of imagery, to seek more information, or perhaps to phrase the solution obtained. The integration of left and right hemisphere processes is also demonstrated by numerous studies which indicate that the use of imagery enhances verbal ability and recall (Senter &

Hoffman, 1976; Tedford & Penk, 1977; Stennett-Mason, 1979).

One assumption is that subjects who display no one dominant mode, e.g. bidirectionals, may have a greater degree of "combinatory play" between the two hemispheres. Such activity may be part of the process which enhances both creativity and verbal ability. In concurrence with this idea, Grady (1976, p. 47) had earlier stated that students need visual media for a balanced brain, and quoted Arnheim (1969): "Rudolf Arnheim suggests that 'man thinks visually', and that 'the visual in fact makes verbal thinking possible.'"

An enlightening example of this was given in a report by Debes (1974) who cited an article he had read in the Journal of Learning Disabilities entitled "Visually Mediated Thinking: A Report of the Case of Albert Einstein." Einstein as an eight year old was doing so poorly in school that his parents entered him into a school in which the approach was founded by the Swiss educator, Pestalozzi. Pestalozzi believed that conceptual thinking is built on visual understanding, and he reportedly said that visual understanding is the basis of all knowledge. Einstein flowered intellectually in the Pestalozzi school, and said years later, in regard to his own thinking, that he thought entirely visually and that he went to words only when his ideas were fully worked out.

Several of today's educators are becoming concerned that our educational system is characterized by a heavily "left-brained (or right-winged) philosophy" (Crinella et al., 1971, p. 2050), valuing linear thought processes and the acquisition and manipulation of language and symbols foremost, at the expense of self awareness, spatial schemata, music, and

the fine arts. Rennels (1976) suggests that this educational crisis can be overcome by encouraging imagination, visualization, and attention to sensory stimuli. A curious contention has been offered by Debes (1974) that the imbalance is fortunately being corrected already, though quite by accident, thanks to visual technology. Debes states that children are becoming visually literate by means of television. This asset prepares them to deal more expertly with their futures, to communicate better with each other, in fact, to achieve all of the things customarily regarded as the proper goals of education. The decline begins when children enter school and begin to be pressed in the direction of verbal activities and forced away from the visual activities in which they have become so skilled. Debes asserts that maintenance of the intellectual development that is begun through television is possible by visual literacy programs, in which the use of pictures and other visual communication is actively pursued.

In summary, several explanations for the lack of statistically significant results in the present investigation have been proposed. Those related to the stimulus quality and scoring were discussed in terms that may suggest improved methods for further studies. The possibility that lateral eye movement may not be intrinsically linked to hemisphere activation/dominance is also considered, with suggestions for a more conclusive determination of the relationship. Finally, the implications of the findings of this study, though not at a level of significance, are discussed in terms of an educational approach which would lead to a greater integration of the asymmetrical hemispheres.

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