THE RELATIONSHIP BETWEEN PERFORMANCE ON CREATIVITY TESTS AND CEREBRAL HEMISPHERIC ACTIVATION AS MEASURED BY DIRECTION OF CONJUGATE LATERAL EYE MOVEMENT DURING MENTAL PROBLEM SOLVING

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ABSTRACT

THE RELATIONSHIP BETWEEN PERFORMANCE ON CREATIVITY TESTS AND CEREBRAL HEMISPHERIC ACTIVATION AS MEASURED BY DIRECTION ON CONJUGATE LATERAL EYE MOVEMENT DURING MENTAL PROBLEM SOLVING

By

Stephen A. Truhon

College age subjects' conjugate lateral eye movements during mental problem solving were used as an index of preferential activation of the cerebral hemispheres. Forty-eight undergraduates (40 right-handed) were seated in front of a hidden television camera. The experimenter sat behind the subject and asked questions designed to be either verbal, spatial, or "creative." The direction of the subject's first eye movement in response to each question was recorded. Afterwards, the subjects completed two creativity tests (the Barron-Welsh Art Scale and the Remote Associates Test) and a handedness questionnaire.

Of the 40 right-handed subjects, both men and women looked significantly more to the right than left when asked verbal and creative questions, and more to the left (not significantly for women, marginally significant for men) when asked spatial questions. Subjects showed a general preference for

looking to the right. No significant sex differences were found in direction of eye movement with respect to problem type. Direction of eye movement was not related to accuracy on the questions. Scores on the two creativity tests were negatively correlated. There were no differences in direction of eye movements among subjects classified as high, medium, or low on creativity.

Although subjects responded according to problem type, they were fairly consistent in their direction of eye movement. For females, but not for males, there were significant correlations of eye movements between problem types. The choice of direction was less likely to affect accuracy for females than for males. These two trends support the hypothesis that females are less lateralized than males.

The results fail to support earlier reports suggesting that creativity is subserved by the left cerebral hemisphere or by both hemispheres. The study questions the reasonableness of considering creativity as a global ability, and suggests instead that creativity is a group of abilities, meaning that the potential hemispheric specialization of each must be considered.

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INTRODUCTION

Cerebral Lateralization

Research beginning in the 19th century disclosed two distinct properties of the human brain, which had been suspected since ancient time: contralateral innervation and hemispheric specialization (Bogen, 1969). By contralateral innervation it is meant that each hemisphere is linked to bodily functions on the opposite side. Thus, the left hemisphere mainly controls functions of the right side of the body, while the right hemisphere mainly controls functions of the left side of the body. Emphasis should be placed on the word "mainly" because the relation is not one-to-one. For example, motor and sensory processes are also controlled by the ipsilateral hemisphere (e.g. Evarts, 1966; Malis, Pribram, & Kruger, 1953; Nakahama, 1958; Woolsey & Fairman, 1946; all cited by Harris, 1975).

By hemispheric specialization it is meant that the two hemispheres do not perform identical functions. The left hemisphere is said to be specialized for "analytic", "propositional", or "sequential" cognitive processes as language and mathematical functions, while the right hemisphere is said to be specialized for "synthetic", "appositional", or "simultaneous" cognitive processes such as visual-spatial and musical functions (Bogen, 1969). This specialization does not mean that one hemisphere cannot perform some functions. Rather each hemisphere is better at some functions than others.

The historically earliest evidence for hemispheric specialization comes from the study of brain injured patients. Patients who have had strokes affecting the left hemisphere typically have hemiplegia on the right side of their body and language disturbance (aphasia). Among non-aphasic patients with left-sided lesions language disturbance is still present although more subtle: for example, it has been shown that non-aphasic patients with left temporal lobe lesions have more difficulty in verbal learning and verbal memory than patients with right hemisphere lesions (Meyer, 1959; Milner, 1958, 1962), and perform more poorly on a test of verbal fluency than patients with right hemisphere lesions (Benton, 1965).

On the other hand, patients with right hemisphere lesions have more difficulty in spatial recognition, e.g., remembering routes, locating places on a map (Benton, 1965).

The conclusions drawn from clinical evidence are supported in studies with normal individuals through such techniques as dichotic listening (e.g., Curry, 1968; Kimura, 1961) and tachistoscopic presentation of dots, when verbal or manual responses are used (e.g., Filbey and Gazzaniga, 1969).

Eye Directionality

Directionality of eye movements during problem solving recently has been proposed as still another index of specialization. When a person is asked a question requiring reflective thought, he shifts his eyes to the left or to the right in the process of solving the problem (Day, 1964). This phenomenon

has long been noted. Foerster (1931) reported that stimulation of the frontal adversive field and the frontal eye field of the brain led to contralateral eye movements in humans. Crosby (1953) concluded that small associative cells, which constitute the parabducens nucleus, send their processes forward through the brainstem. The fibers from the cells end around the oculomotor nerve and supply the medial rectus muscle of the contralateral eye.

It is known that the operations of the two hemispheres are coordinated at various levels of the nervous system (Horridge, 1968). This holds true for lateral eye movements (Crosby, 1953). In addition if there are competing responses generated by each hemisphere, this competition is mediated by mutual inhibitions across the transverse commissures (Sherrington, 1947; cited by Kinsbourne, 1970b). Thus an individual will act one way or the other in a unified and coordinated manner.

Kinsbourne's Attentional Model

A specific model linking conjugate lateral eye movements with hemispheric specialization has been suggested by Kinsbourne (1970a, 1973). A major presupposition of the model is that the cerebrum is a highly linked system, such that any two cortical neurons are only a few synapses away from each other This allows for interaction between functions within the same hemisphere.

Building on these facts about the cerebrum Kinsbourne (1970a, 1973) has proposed an attentional model based upon the principles of contralateral innervation and hemispheric specialization. Since in the human brain certain cognitive functions

are lateralized, these lateralized functions should interact with ipsilateral functions such as eye movement. Thus if someone is trying to solve a verbal problem, eye movement will be to the right, because of the interaction between left hemisphere control of verbal thought and contralateral eye movement. The opposite would occur when solving spatial problems.

Furthermore this model prevents activation of the inappropriate hemisphere. If one is looking to the right, this will inhibit activation of the right hemisphere. Thus looking to the right should predispose the left hemisphere to solve problems in a verbal or analytic manner. In other words, looking in one direction prepares the contralateral hemisphere to receive information for its lateralized cognitive functions, and prevents the ipsilateral hemisphere from processing the incoming information. Therefore looking in the appropriate direction (to the right on verbal problems, to the left on spatial problems) should result in more correct responses.

Evidence for Kinsbourne's Attentional Model

Kinsbourne (1970a, 1973) has reported evidence supporting his attentional model. Right-handed young adult subjects were required to detect gaps in squares. Under standard conditions in which gap detection was the only requirement, there was no significant difference in detection of gaps on the left of the square from the right of the square. However in a subvocalization condition in which the subjects were required to remember six words they had just heard, there was better detection of gaps

on the right of the square than on the left of the square. Presumably, subvocalization activated the left hemisphere and thus biased the subject's attention to the right, resulting in more errors on the left.

With respect to eye movements, Kinsbourne (1972) presented several types of problems--verbal, spatial, and numerical--for undergraduate college subjects to solve. To control for background features, the experimenter sat behind the subject and the subject's eye movements were recorded on a hidden television camera. For right-handed subjects direction of eye movement was related to problem type--to the subject's right on verbal problems and to the subject's left on spatial problems, although the effect was weaker on the spatial problems.

These differences have been confirmed by Kocel, Galin, Ornstein, and Marrin (1972). They found that subjects between 18 and 36 years of age looked to the right significantly more than chance on a combination of verbal and mathematical items, but on a combination of spatial and musical items their left looking was not significantly different from chance.

Bakan's Personality Model

Another and quite different interpretation of this eye movement phenomenon has been suggested by Bakan (1971). Bakan, like Kinsbourne (1970a, 1973), assumes that direction of the eye movement indicates greater activation of the contralateral hemisphere. However other data (Duke, 1968) indicate that individuals are consistent in their direction of eye movement, provided the problems require reflective thought. Bakan (1971)

believes this indicates that the individuals show a regular, preferred activation of the cerebral hemisphere contralateral to the eye movement. Since each hemisphere subserves specific cognitive functions (Bogen, 1969), Bakan (1971) concludes that differences in direction of eye movement reflect differences between individuals in hemispheric functioning and these differences should be expressed in personality differences.

Evidence for Bakan's Personality Model

What, then, are the characteristics of left and right movers and do they correspond to the known differences in the functioning of cerebral hemispheres?

Many of the studies (Day, 1964, 1967, 1970) used schizophrenics as subjects, which raises questions about the generalizability of these findings. Among these schizophrenics, left movers described their characteristic mode of anxiety as an internally perceived feeling, i.e., tension (Day, 1964). Their distribution of attention is described as internalized, subjective, passively verbally expressive ,and more reactive to auditory and subjective visceral stimuli (Day, 1967).

Among college undergraduates, left movers, when compared with right movers, score higher on the following scales of the Cattell-Eber 16 Personality Factor Test: emotional stability (e.g., "When people don't listen, I remain patient"), suspiciousness (e.g., "Most people tell the truth only when it won't hurt them") and shrewdness (e.g., "After a busy day, ideas keep running through my mind") (Etaugh, 1972). They also seem to show a

greater balance than right movers between mathematics and verbal scores on the Scholastic Aptitude Test (Bakan, 1969; Weiten & Etaugh, 1973). Left movers also are more likely to choose "soft" majors in college (humanities and social sciences) (Bakan, 1969). Finally, they have a higher frequency of alpha brain waves (Bakan & Svorad, 1969) and are more hypnotizable (Bakan, 1969), though the significance of this association is unclear (Bakan & Svorad, 1969).

Disagreement has arisen about the supposed assertiveness of left movers. With his schizophrenic patients, Day (1970) found left movers' language style less assertive than that of right movers (i.e., they were more likely to say "I'm terribly hungry" rather than "I've got to get something to eat"). However, with college students Etaugh (1972) found that on the Cattell-Eber 16 Personality Factor Test left movers scored higher than right movers on the assertiveness scale (e.g., "It's fun to tell a lie with a straight face"). Etaugh (1972) attributed this disagreement with Day's (1970) finding to the testing procedures--Day based his assertions on observations--and to the population tested--the schizophrenics Day examined are not so consistent in their direction of eye movements as usually reported (Duke, 1968). It also appears that assertiveness in language style may be only an aspect of general assertiveness, i.e., those whose language is assertive are probably assertive in general, but this relationship is not necessarily one-to-one.

The above-mentioned characteristics of left movers fall within a pattern. The right hemisphere is considered the

synthetic or emotional hemisphere. Left movers appear more concerned with emotional subjective feelings (although the finding by Etaugh (1972) that they are more emotionally stable appears to contradict this). They are more concerned with how events affect themselves than with how they affect others.

Among schizophrenics, right movers describe their characteristic mode of anxiety as a panic feeling with externalized perception of cause, i.e., fear (Day, 1964). Their distribution of attention is described as externalized, actively responsive, and more reactive to visual-haptic stimuli (Day, 1967).

Among college undergraduates right movers show greater discrepancy than left movers between mathematics and verbal scores in favor of mathematics, on the Scholastic Aptitude Test (Bakan, 1969; Weiten & Etaugh, 1973), take less time on concept identification tasks (Weiten & Etaugh, 1973), and perform better on tasks requiring visual attention, such as the Stroop Test (Bakan & Shotland, 1969). They also tend to pick "hard" majors in college (Mathematics and physical sciences) (Bakan, 1969).

Right movers show characteristics of the left or analytic hemisphere. They are more objective in evaluating experiences and tend to be more interested in external rather than internal experiences.

Resolution of the Models

The disagreement between these two models is apparent in the types of problems used. Kinsbourne's (1970a, 1973) model

presumes that direction of eye movement is tied to the problem type used - verbal or spatial - while Bakan's (1971) model presumes only that the problem require reflective thought.

Kinsbourne (1972) criticized the studies of Bakan and others for not controlling for content of questions and distracting background features. However, these criticisms do not account for the consistency of results. The only difference in procedures is the position of the experimenter. In Kinsbourne's (1972) study the experimenter sat behind the subject (E-behind-S), while Day's (1964) procedure had the experimenter sit in front of the subject (E-facing-S).

Gur, Gur, and Harris (1975) tested subjects in both the E-behind-S and the E-facing-S conditions. They found that in the E-facing-S condition, subjects moved their eyes predominantly in one direction regardless of problem type. In the E-behind-S condition right-handed subjects moved their eyes according to problem type--to the right for verbal problems, to the left for spatial problems.

Gur et al. (1975) suggest that a person's natural response when asked a problem is for his eye movements to correspond to problem type. The salient stimulus in the E-behind-S condition is the problem. However, the E-facing-S condition is more personal, and, as a result, may be more threatening. They found that subjects were more often correct when they looked in a direction contralateral to the hemisphere that should be used. Therefore in a threatening condition, subjects revert to basic processes and move their eyes in a preferred, and sometimes wrong direction.

Meskin and Singer (1974) did a similar study, using the kind of reflective questions employed by Bakan (1969). Subjects were asked these questions by means of head phones in two conditions: when the experimenter was present and facing the subject, and when the experimenter was absent. Subjects were classified as left and right movers on the basis of the combined scores for both conditions. The results showed that, left movers made more eye movements to the left in the experimenter present condition than in the experimenter absent condition, while right movers made fewer eye movements to the left.

It is questionable to combine scores in such a way if they create such differences. But it does seem clear that the presence or absence of the experimenter affected the subject's eye movements.

Meskin and Singer's (1974) interpretation of the effect of the experimenter in the E-facing-S condition is somewhat different from Gur et al.'s (1975). They suggest that a person's face, being a complex stimulus, is distracting during problem solving and remembering. Subjects respond to the distraction by shifting their gaze and, given the choice of direction, subjects look in a preferred direction. This explanation does not explain why one direction is chosen over another, unless we borrow from Gur et al.'s (1975) idea that a threat is perceived in the complexity of the human face.

The results from Gur et al.'s (1975) and Meskin and Singer's (1974) studies suggest an accommodation between Kinsbourne's attentional model and Bakan's personality model

when the precise circumstances of testing are taken into account. Kinsbourne's model predicts the direction of eye movement according to problem type, but this specificity can be overridden in certain circumstances (e.g., the experimenter sitting in front of the subject). In such a case we would observe subjects with a characteristic direction of looking which is indicative of a preferred cognitive mode (Bakan's model).

Handedness

One point of note in several of the studies mentioned earlier (Gur, et al. 1975; Kinsbourne, 1970a, 1972, 1973) is that the results hold only for right-handed subjects. Evidence indicates that left-handers are less lateralized than right-handers (Benton, 1962; Hécaen & Ajuriaguerra, 1964; Hécaen & Sauget, 1971). Thus with respect to eye movements, it would be expected that left-handers would show the pattern of looking to the right during verbal problems and to the left during spatial problems less reliably than right-handers. Indeed this is the case in the E-behind-S condition (Gur et al.,1975; Kinsbourne, 1972). In the E-facing-S condition no differences between right and left handers have been found (Etaugh, 1972; Gur et al., 1975).

Sex Differences

Recent evidence, some of which is reviewed by Harris (Note 1) and Harshman and Remington (Note 2), suggests that women are less lateralized than men. For example, men's scores on a proverb test dropped after left-temporal lobe operations, while women's scores were unaffected (Lansdell, 1961). Of patients

with right-temporal lobectomies, men had lower Wechsler "non-verbal" scores than women (Lansdell, 1968). These findings suggest that, when compared with men, right hemisphere damage is less likely to affect women's non-verbal skills, while left hemisphere damage is less likely to affect women's verbal skills. With respect to eye movements one would expect the classification of movers to be more difficult for females and for those who could be classified to show less clear cut personality differences between left and right movers. On eye movement tests, the evidence is mixed. Duke (1968) reported that women are less consistent than men in their direction of eye movement. Etaugh (1972) found no sex differences in direction and consistency of eye movements.

Many other studies have ignored the question of sex differences (e.g., Kinsbourne, 1972), while others have only used male subjects (e.g., Gur et al., 1975; Meskin & Singer, 1974).

The Nature of Creativity

One problem in discussing creativity is the lack of agreement about what creativity is. Each researcher seems to have his or her own definition. To arrive at a consensus definition of creativity is a long and tedious process. The definition arrived at, e.g., "Creativity is the association of elements, previously distinct, in a novel way which is goal directed.../and/ results in a novel product which not only fits in with reality but also may extend the bounds of reality."

(Truhon, Note 3), may still be so vague that definition of the terms used in the definition may seem required.

Creativity is typically conceived of as a result of divergent thinking, i.e., thinking in which there is no one correct answer. Indeed, the image of the creative person turning out idea after idea is a realistic one. However, if one focuses only on this aspect, one misses an important part of the creative process: the evaluation phase. These ideas must be evaluated and compared for their practicality. This phase, though less glamorous than the idea output phase, is just as important. Therefore any conception of the creative process must include divergent and convergent thinking (Guilford, 1959).

Creativity and Lateralization

The major question to be addressed in the current research is whether there is a relation between hemispheric specialization and creativity. Because of the definitional problems mentioned earlier and the impracticality of directly measuring creativity--one cannot just ask a subject to be creative at this particular moment--it is more difficult to test creativity than verbal and spatial ability. As a result, it is not uncommon to find low correlations among putative tests of creativity (Wallach & Kogan, 1965). This makes it especially difficult to conceptualize the relation between creativity and lateralization.

There have been attempts to explain creativity in neurological terms. In one study (Hutton & Basset, 1948), patients with lobotomies were reported to have given stereotyped answers

and to have had great difficulty being original or creative in the Rorschach Test and the Thematic Apperception Test. It is questionable, however, whether this diminished performance was related to the lobotomy itself (probably in the prefrontal area--the report is not specific), since other evidence reveals no difference between lobotomized patients and neurotics on tests of creative ability (Ashby & Basset, 1949). Since we are interested in the relation between creativity and hemispheric specialization, it is unfortunate that neither of the studies cited here report whether the left or right lobe was removed.

Model I: Creativity as a Right Hemisphere Function

One approach to the question of creativity and laterialization has been to associate creativity with right hemisphere functions. In noting that certain aspects of speech are affected by right hemisphere disease, Critchley (1962) reported:

> ...Creative literary work, demanding a particularly high level of performance, may, I submit, be severely affected in such circumstances (i.e., right hemisphere disease). I have seen striking examples of this phenomenon in professional writers who have been afflicted with disease of the minor hemisphere. (p. 212)

One would assume from the little that Critchley (1962) reported that these professional writers retained their mechanical skill but lacked that "spark of creativity" that distinguished them as writers.

Personality characteristics of creative persons, such as subjectivity, capacity for visual imagery, and interest in humanities (Barron, 1969), resemble those of the left mover.

In his review of the eye movement phenomenon Bakan (1971) reported (without citations) that left movers were more creative than right movers.

The experimental data for this model are not especially clear. Hanrad (1972) had graduate students in mathematics rank their mathematics professors from least to most creative. The sample of mathematic professors was small, some students did not include all the professors in their rankings, and the students were assumed to know what creativity in mathematics meant. Despite these methodological problems the results showed higher rankings for left than for right-moving mathematics professors. This finding is bolstered by Hanrad's (1972) finding that among subjects with at least some college education left movers scored higher than right movers on the Remote Associates Test (Mednick & Mednick, 1967), a creativity test requiring the subject to find a fourth word which is related to three seemingly unrelated words.

Despite the problems of small sample size and incomplete ratings on some professors, Hanrad's (1972) findings are interesting in that they appear to contradict Bakan's (1969) finding that better mathematical skills are usually found in right movers. It is possible that the left hemisphere is necessary for mathematical skill, but what distinguishes creative mathematicians from their less creative colleagues is their use of the right hemisphere.

Hanrad's (1972) finding that left movers are more creative than right movers has found support in apparently only one other study. Hines and Martindale (1974) had subjects wear goggles

which forced them to look to the left or to the right. In a series of three experiments, only in one experiment was a significant difference found: males scored higher on the Remote Associates Test when they were forced to look to the left. No differences were found for females or when the Alternate Uses Test (Christensen, Guilford, Merrifield & Wilson, 1960), a creativity test requiring the subject to think of unusual uses for common objects, was used.

There is an assumption underlying Hines and Martindale's (1974) study which does not appear justifiable. Even if there are differences in creativity between left and right movers, it does not necessarily follow that one can make someone more creative by forcing him to look in the "appropriate" direction while solving a problem. Creativity may be a cognitive style requiring long and constant practice.

Other studies have not supported Hanrad's (1972) finding that left movers are more creative than right movers. Smith (1972) found no differences in creativity, as measured by the Remote Associates Test, between left and right movers in a college population.

Leonowich (1972) used the Barron-Welsh Art Scale (Barron & Welsh, 1963) as her measure of creativity. On this test subjects are required to indicate whether they like or dislike drawings. High scores are achieved by liking complex, asymmetrical drawings and disliking simple, symmetrical ones. Leonowich (1972) was interested not only in direction of eye movement but also consistency

of direction. While there were similarities between creative persons as measured by the Barron-Welsh Art Scale, and what she called "right hemisphere dominants" (i.e., consistent left movers) in discerning order and recognizing principles of organization in a sentence completion task, this relationship was not significant.

As can be seen Model I does not have strong support. Its major support, Hanrad's (1972) study, has serious limitations.

Model II: Creativity as a Combination of Left and Right Hemisphere Functions

Another approach to the question of the laterality of creativity is to see creativity as a combination of left and right hemisphere functions. Based on introspection, creative writers, mathematicians, and chemists report using two different kinds of thought when thinking creatively (Ghiselin, 1952). For example, writers report being dependent on nonverbal images to express verbal ideas. Mathematicians report the illumination (aha!) part of the creative process as a chaos from which one builds order through the use of calculations.

These kinds of thought correspond to the terms "propositional" (left hemisphere) thought and "appositional" (right hemisphere) thought suggested by Bogen (1969). This ability to use both hemispheres suggests that the corpus callosum, the bundle of nerve fibers connecting the two hemispheres, should play an important role in the creative process (Bogen & Bogen, 1969). Thus it is the person who is capable of both kinds of thought and

integrates them through the corpus callosum who possesses the capacity for creativity.

The evidence for this model is not especially strong. Martindale (1975) reported that highly creative persons, as measured by the Alternate Uses Test, have similar levels of alpha waves in each hemisphere, while medium-creative persons have more alpha in the right hemisphere than in the left. These findings suggest that evidence supporting Model I may be produced by people of moderate creativity who use their right hemispheres more.

If creativity involves both hemispheres, then creative persons should not depend more on one hemisphere than the other. Thus, they should be less lateralized than those who are not creative. Dusewicz (1968) came to this viewpoint from another approach.

Based on some questionable interpretation of studies on creativity, Dusewicz (1968) suggests that creativity is related to psychological instability. This notion that "genius is close to insanity" is actually rejected by articles Dusewicz cites (Cattell & Drevdahl, 1955; MacKinnon, 1965) and other theorists (Kris, 1952; Kubie, 1958). Dusewicz (1968) cites Palmer (1963) that those who do show non-lateralized functions are more likely psychologically deviant or unstable. He, therefore, hypothesizes that, since creativity and incomplete lateralization are both related to psychological instability, creativity and incomplete lateralization should be related to each other.

Dusewicz (1968) measured creativity by means of teacher ratings of students on a scale supposedly developed by Guilford (1962). (This article by Guilford (1962) contains no such scale.) Lateralization was measured by concordance among handedness, footedness, eyedness, and earedness. Correlations between creativity and lack of concordance were negative, as predicted, but not significant.

A study by Smith (1972) also lends support to this model. In his examination of the relation between creativity and eye movement, Smith's (1972) classification of subjects included a third group, "middle movers", i.e., those who did not show a preference for one direction over another. These middle movers scored significantly higher than right and left movers on two measures of creativity: the Remote Associates Test and on the Fluency scale of the Torrance Figural Test (Torrance, 1966), which asks the subject to produce drawings incorporating various lines and shapes.

The major problem with models 1 and 2 is that they tend to globalize creativity. Guilford (1971) has noted that creativity is not one ability but rather a series of abilities. That may explain why creativity tests have such low intercorrelations (Wallach & Kogan, 1965). It would thus seem appropriate to examine the lateralization of individual creative skills.

Model III: A Creative Skill Is Associated With The Hemisphere Contralateral to the One Normally Associated With That Skill

This model is a variant of the second model. It suggests that both hemispheres are involved in the creative process, but

the hemisphere crucial for creativity to occur is the one contralateral to the one normally associated with that skill. Thus, for verbal creativity the right hemisphere is crucial; for the nonverbal creativity the left hemisphere is crucial.

The evidence for this model is slight. Critchley (1962) reported that professional writers with right hemisphere lesions suffered impairment of their literary talent. Hines and Martindale (1974) found in one case that scores on the Remote Associates Test, a verbal creativity test, were higher when subjects were forced to look to the left. Likewise Hanrad (1972) found that creative mathematical ability was related to left looking, while Bakan (1969) found mathematical skills to be associated with right looking.

All the above-mentioned evidence suggests that the right hemisphere is necessary for creativity in skills normally associated with the left hemisphere. However, the converse does not appear true. Alajounine (1948) reported the case of a painter whose skill did not diminish when he suffered aphasia. Thus, painting, a right hemisphere spatial skill, was not affected by the loss of language, a left hemisphere skill.

Model IV: A Creative Skill Is Associated With the Same Hemisphere Normally Associated With That Skill

Still another model is suggested not so much by empirical evidence as by some questions about the way creativity is assessed. In most of the eye movement studies listed above, the subject's eye movements were elicited in the E-facing-S condition.

If, as Gur et al. (1975) and Meskin and Singer (1974) suggest, the E-facing-S condition interferes with the problem solving process, then this procedure may be obscuring the cerebral basis for creativity. This could explain why the results seem to contradict each other. The question arises: what would happen in the E-behind-S condition?

A second problem with the above-mentioned studies is that creativity is regarded as a personality characteristic and measured indirectly, i.e., subjects were classified as left, right, or middle movers and their scores on creativity tests were compared. If one follows Kinsbourne's (1970a, 1973) attentional model, the question should be: in which direction will subjects look if they are given problems requiring creative thought?

The attentional model predicts that, when given creative verbal problems, subjects will look to the right; when given creative nonverbal problems, they will look to the left. The model makes no statement about whether during the creative process one or both hemispheres are activated.

Thus, it is difficult to make a prediction about which of the four models will be supported by this study. The first two models seem limited by their global view of creativity. The current study should provide some basis for comparing the third and fourth models.

METHOD

Subjects

Seventy-two college-age subjects (Ss) were tested. However, because of necessary changes in procedure (e.g., position of the television camera, how it was disguised), only 48 Ss were tested under the conditions to be described here. The remaining 24 Ss were included in certain additional analyses. Of the 48 Ss, 40 (20 men and 20 women) were right-handed as determined by a handedness questionnaire (Humphrey, 1951). The remaining eight Ss were either left-handed or ambidextrous. All Ss were volunteers from undergraduate psychology courses at Michigan State University.

Materials

In most studies of eye movements (Gur et al., 1975; Kinsbourne, 1972) three types of questions have been used: verbal (proverb explanation), numerical (arithmetic problem solving), and spatial (visualization and recognition of spatial relationships). Since the pattern is not clear for numerical problems (e.g., Gur et al., 1975), only verbal and spatial were used in the current study.

The creative problems used were drawn from the Remote Associates Test (RAT) (Mednick & Mednick, 1967) so as to insure comparability with previous studies (e.g., Smith, 1972). The RAT consists of a series of three seemingly unrelated words. The

subject is asked to find the fourth word which is related to all three. For example, if given the words "cookies," "sixteen," and "heart," the S should respond with the word "sweet." There are 30 such items on the test (see Appendix B).

Although there has been criticism that doing well on RAT has little relation to creative ability, the RAT correlates fairly well with faculty ratings of the creativity in architecture and psychology graduate students. It also is fairly good in predicting which scientific research proposal will be accepted and the number of awards won by technicians.

From a pilot study of 20 Ss, 10 of the more frequently correct RAT items were chosen. (Some of the more frequently correct items had to be rejected because of homonym problems.)

The 10 verbal items consisted of proverb explanations (Explain "All that glitters is not gold."), spellings (Spell "accommodate."), and analogies (Horse is to cavalry as foot is to _____.).

The 10 spatial questions were taken from Gur (1973). Examples include: "Imagine the map of the United States. In what direction is Chicago relative to Minneapolis?"; and "Visualize sitting in front of a typewriter. Where is the letter 'R' relative to 'B'?" The eye movement test consisted of 30 items, 10 creative, 10 verbal, and 10 spatial (see Appendix A).

In the second part of experiment three tests were given. The first test was an alternate form of the RAT (see Appendix B).

Another test of creativity is the Revised Art Scale on the Barron-Welsh Art Scale (BWAS) (Barron & Welsh, 1963). This

test was used to provide some comparability with Leonowich's (1972) study. The BWAS consists of 86 drawings. The subject is asked to indicate his like or dislike for each drawing. Those items that best differentiated artists from non-artists were included in computing the final score. This test assumes that artists are more creative than non-artists. High scores are achieved by liking complex asymmetric drawings and by disliking simple symmetric drawings. The Revised Art Scale corrects for response bias by including an equal number of like and dislike items in computing the final score.

The BWAS is considered an art test and has proved effective in distinguishing artists from non-artists and in predicting ability in creative writing classes. However, it has had practical application in science, e.g., in predicting originality in scientists, medical students, and Ph.D. candidates in science.

Handedness was determined by a 20 item questionnaire (Humphrey, 1951), developed for use in England and modified for the current study to allow for cultural differences between England and the United States (e.g., substituting baseball questions for cricket). Two points were given for a response indicating the right hand, one point for indicating either hand, and zero points for indicating the left hand. A subject with a score of 30 or more out of a possible 40 was considered right-handed (see Appendix C).

Procedure

The experiment room contained a television camera, positioned at eye level for the seated subject. The camera was covered

with burlap with a small hole, through which the subject could be seen. The burlap made it impossible to see the camera, although by the shape it was obvious that a camera was there. A chair stood two feet away facing the camera. Two feet behind this chair was another chair, facing the same direction. Next to this chair was a tape recorder. A poster board was placed to the left of the front chair to prevent the subject from being distracted by other objects in the room. To the right of the chair was a window with the shade drawn.

An observer (O) in an adjoining viewing room watched the proceedings on a television monitor and recorded eye movements.

Subjects were informed when volunteering for the experiment that they would be observed by video equipment. The S was seated in the front chair and asked to look straight ahead (into the camera). The experimenter (E) and the O together checked whether the S's eyes could be clearly seen and made any necessary adjustment in the camera's height before starting.

The E then sat in the back chair, turned on the tape recorder to record the S's responses, and read the following instructions:

"There are two parts to this experiment. In part one, I'm going to ask you some questions. As I've already explained, we will videotape the session in order to keep a record. The tape will be strictly confidential, as will be your scores. To help me do this, please concentrate on the items, remain seated, and don't move around during the questions. Part one will take about 20 minutes."

"In part two you will be asked to complete three questionnaires. Please complete them in order I give them to you. During this part you will not be videotaped. Part two should take no longer than 40 minutes."

The order of the verbal and spatial questions was counterbalanced. The creative questions were always asked last.

The instructions for the verbal questions were as follows:

"I am going to ask you some questions. I will ask you to spell words, explain proverbs, and solve analogies."

The 10 verbal questions were then read (see Appendix A).

The instructions for the spatial questions were as follows:

"I am going to ask you some questions. Some will require you to imagine yourself in certain situations, while others will ask you to explain where things are."

The 10 spatial items were then read (see Appendix A).

The instructions for the creative questions were as follows:

"I am going to present three words to you. They may seem unrelated but there is a fourth word which is related to them. I will ask you to find that fourth word. For example, if I gave you the words "Southern" "console," and "station," you should reply "comfort." There is the alcoholic product "Southern comfort;" a

synonym for "console" is "comfort;" and "comfort station" is a euphemism for bathroom. Do you understand?"

The creative questions were then read (see Appendix A).

The E recorded the S's vocal responses onto the question sheet. However, for lengthy responses such as the proverb explanations, the E consulted the tape recorder at another time.

The O watched the S's eyes on the television monitor. When the S was asked a question, the O recorded on a premarked sheet whether the S's first eye movement in response to the question was to the left or to the right. The first eye movement was chosen because it correlates highly with the subsequent percent of time spent looking in that direction (Gur et al., 1975). This procedure was continued for all 30 items. Some of the Ss were recorded on videotape to check for the O's reliability.

After the creative questions were completed, the end of part one was announced and the tape recorder was stopped. Any questions at this point were answered. The E then brought the S to another room for the administration of the BWAS, the RAT Form B (see Appendix B), and the handedness questionnaire (see Appendix C) in that order.

RESULTS

Reliability of Observer's Judgment

Five Ss (four male, one female) from the 48 tested were videotaped for purposes of obtaining interjudge reliability. A second observer was given the same instructions as the O: to record on the pre-marked sheets whether the S's first eye movement in response to the question was to the left or to the right.

Both observers agreed that there had been some eye movement on 130 out of a possible 150 questions asked (87% agreement). Agreement as to direction was only moderately good (78%, tetrachoric $r = .554$, $p < .001$) when compared to earlier studies--100% in Kinsbourne's (1972) study, 87% in Meskin and Singer's (1974) study. There was less agreement for those cases in which one or both observers thought no eye movement had occurred were included (71%, $r = .450$, $p < .001$).

There are several possible reasons why these agreement percentages are only moderately good. These five Ss were among the first Ss tested. The O reported that she felt that her judging ability improved as the experiment went along, and the eye movements of later Ss were more clearly to the left or to the right. While it is possible that the second observer was too naive and brought down reliability, agreement between the E

and the O, when the E viewed the tape, on those occasions when both agreed that there had been some eye movement, was no better than before (75%). In any event, while these reliability figures are comparably lower than previous studies, the choice of subjects for measuring reliability may have lowered the reliability figures.

Direction of Eye Movement With Respect to Problem Type

The percentage of eye movements to the left for each problem type for each S was calculated. This was done to equate the responses for each S, since no eye movements were recorded on some occasions because, for example, the S's head moved out of camera range, or the S's eyes closed. Table 1 indicates that Ss moved their eyes to the right with significant frequency on verbal and creative problems and to the left (but not significantly) on spatial problems. This difference in responding to spatial and verbal problems is confirmed by multi-dimensional scaling techniques (see Appendix D).

These findings correspond with findings by Kinsbourne (1972) that the lateralization effect was weaker for spatial problems than for verbal problems and by Kocel et al. (1972) that subjects looked to the right significantly more than chance on a combination of verbal and mathematical items, but on a combination of spatial and musical items their left looking was not significantly different from chance. This suggests that the spatial problems, either by their presentation or content, may be obscuring the cerebral basis of spatial ability. It

TABLE 1

Percentage of Eye Movements to the Left

Compared to Chance (μ = 50%)

		Spatial	Verbal	Creative
Females (N = 20)	$\bar{X}$	59.55	31.20	30.45
	S	24.37	18.80	23.62
	t	1.708	4.359***	3.608***
Males (N = 20)	$\bar{X}$	61.75	29.75	30.05
	S	24.64	18.68	19.05
	t	2.079#	4.725***	4.565***

$.06 < p < .05$
*** $p < .001$

could be that spatial may not be so lateralized as is believed. Or another factor--a general tendency to look to the right--may be obscuring the relationship between spatial ability and right hemisphere specialization.

Sex Differences

There did not appear to be any sex differences in the direction of eye movement with respect to problem type (see Table 1 and Figure 1). On spatial problems, six of the 20 males and six of the 20 females made fewer than 50% of their eye movements to the left. On verbal problems, three males and two females had more than 50% of their eye movements to the left. On creative problems, two males and three females had more than 50% of their eye movements to the left.

Analysis for Individuals

It is possible that the group findings displayed in Table 1 may be obscuring individual differences. Table 2 lists the correlations of eye movements to the left between the problem types. Since these correlations are all positive, it would seem that each individual has a preferred direction of eye movement. However, there was not much variation among individuals. To use Duke's (1968) terminology, most Ss would have to be considered right movers.

One surprising finding was the low correlation of direction of eye movements between creative and verbal problems for males, especially since the data from Table 1 show that males had

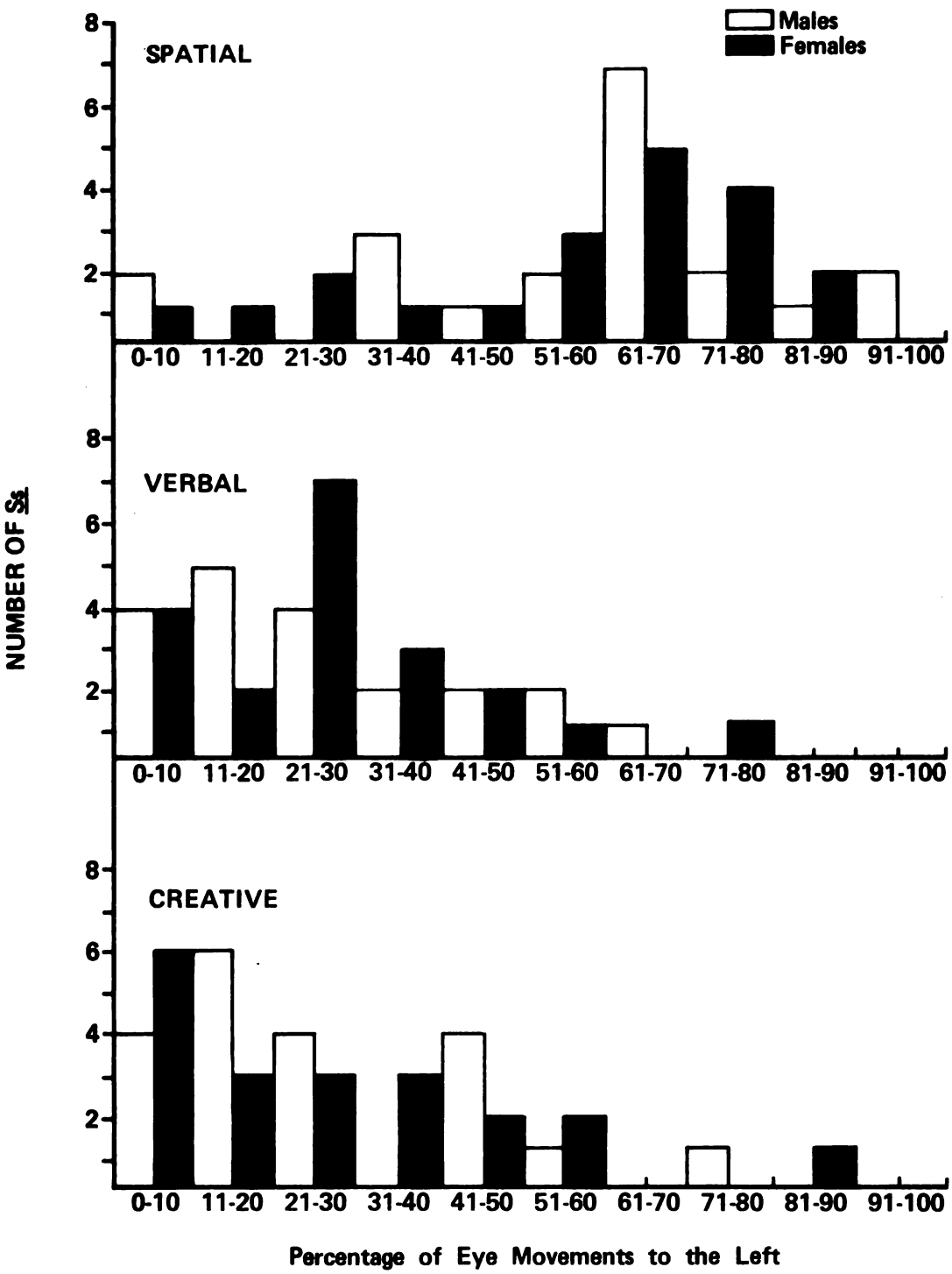

Figure 1. Percentage of Eye Movements to the Left According to Problem Type for Individual Subjects.

TABLE 2

Correlations of Percent of Eye Movements to the Left Between Problem Types for Males and Females

	Spatial	Verbal	Creative
	Females (N = 20)		
Spatial		.445*	.664**
Males (N = 20)			
Verbal	.353		.546*
Creative	.403	.071	

* $p < .05$
** $p < .01$

moved their eyes to the right with significant frequency on those problems. It is possible that, even though both types of problems have verbal features, they involve different processes.

All the correlations for the females were significant, suggesting that they all cluster together. Despite the fact that females as a group responded selectively to problem type, the individual data suggest that in attempting to solve a problem, it makes little difference for individual females what kind of problem is asked. Since most females were right movers, it would seem that they make use of language processes in solving a broader range of problems than males. Therefore, it appears more important for males that the direction of their eye movements corresponds to the problem type. However, if females are less lateralized than males, as has been suggested (Harris, Note 1; Harshman & Remington, Note 2), then it could be that individual females are so consistent in direction of looking, despite problem type, because the selectivity of responding according to problem type is not so necessary as it is for males.

Accuracy and Direction of Eye Movement

Another consideration was whether the direction in which Ss looked was related to the accuracy of the response. Gur et al. (1975) found that in the E-behind-S condition, right-handed Ss did better on verbal problems when they looked to the right, and in the E-facing S condition, on spatial problems when they looked to the left.

Therefore, for each set of problems those Ss were examined who had made at least two eye movements in each direction. To be included in this analysis a subject had to look twice to the right and twice to the left in a set of 10 problems. Most subjects satisfied this criterion: ranging from 13 of 20 females on the creative problems to 17 of 20 females on the spatial problems, the males falling between those extremes. A response was scored as accurate if it was correct and complete, inaccurate if it failed to meet either criterion. Thus, answering that Chicago is southeast of Minneapolis would be accurate, while answering either south or east would be inaccurate. The percent accurate for eye movements to the right and to the left were calculated and a t test was performed.

The results are summarized in Table 3. Contrary to predictions there was no relation between accuracy and direction. The strongest difference in accuracy was for males on spatial problems. Males were more accurate on spatial problems when they looked to the right, contrary to evidence by Gur et al. (1975). There is also a suggestion in the scores that accuracy was affected more by direction for males rather than females. This would fit in with evidence that men are more lateralized than females (Harris, Note 1).

Creativity and Direction of Eye Movement

Because of the debate whether creative persons are left movers or middle movers, the relation between creativity and direction of eye movements was examined. The highest score on

TABLE 3

Percent of Accurate Answers for Each Direction of Eye Movement According to Problem Type

Problem Type		Spatial		Verbal		Creative	
Eye Direction		Left	Right	Left	Right	Left	Right
Males	$\bar{X}$	28.0 <	43.5	34.9 <	45.2	28.3 <	34.7
	S	19.8	26.9	28.0	19.9	30.5	23.0
	t	1.797		1.081		.651	
	df	30		26		30	
Females	$\bar{X}$	38.5 >	34.6	35.9 <	48.6	44.0 >	39.9
	S	25.5	28.8	29.7	23.0	32.1	15.9
	t	.406		1.311		.396	
	df	32		30		24	

N.B. Only Ss who made at least two eye movements in each direction are included for each problem type. N of Ss ranges from 13 to 17.

the BWAS was arbitrarily dropped so that the remaining 39 Ss could be placed into three groups of 13--high, medium, and low in creativity. Ties at the cutoff points (13th and 26th) were decided by a coin toss. An analysis of variance for repeated measures was performed using the percentage of eye movements to the left as the dependent measure. The same procedure was done using the RAT.

It was expected that creative persons would show more eye movement to the left and that they would more likely show this movement on creative problems--a creativity by problems interaction. However, as can be seen from Tables 4 and 5, the only significant result was the difference in response to the problem types, which was already known from Table 1.

This analysis does not disclose whether creative persons were middle movers. Those who scored in the Low and Medium groups could be extreme left and right movers, while those who scored in the High group could be more balanced. Thus, the groups could have similar means but different variances. Therefore, tests of homogeneity of variance were performed on the data in Tables 4 and 5. The results, which are summarized in Table 6, showed that in both cases there was a lack of homogeneity of variance.

To match the model that creativity involves both hemispheres, variance should decrease as one moves from the Low to the High group. This pattern holds when the BWAS is used as criterion for creativity, but not when the RAT is used.

TABLE 4

Analysis of Variance Comparing Creativity (BWAS)

and Direction of Eye Movements

Source	SS	df	MS	F
Total	743.957	116		
Between Ss	295.077	38		
Creative	1.686	2	.843	-
Error	293.391	36	8.150	
Within Ss	448.880	78		
Problems	238.731	2	119.366	44.857**
Problems X Creativity	18.546	4	4.637	1.743
Error	191.603	72	2.661	

** $p < .01$

TABLE 5

Analysis of Variance Comparing Creativity (RAT)

and Direction of Eye Movements

Source	SS	df	MS	F
Total	819.081	116		
Between Ss	378.821	38		
Creative	15.487	2	7.744	-
Error	363.334	36	10.093	
Within Ss	440.260	78		
Problems	254.638	2	127.319	53.29**
Problems X Creativity	13.604	4	3.401	1.424
Error	172.018	72	2.389	

**p < .01

TABLE 6

Variances of Percentage of Left Eye Movements for Low, Medium, and High Groups on Measures of Creativity

	Low	Medium	High
BWAS	5164	1814	1557
RAT	165	4159	2926

The Relation Between the Tests of Creativity

In the following analyses additional Ss were included, since the changes in experimental procedure should not have affected scores on the written tests. Because of the question whether creativity is one global ability, correlations between scores on the BWAS and the RAT were performed. It was expected that, even though the tests may be quite different in content, there should be, at least, a low positive correlation.

However, as can be seen from Table 7, the correlation between the two tests was significantly negative. Further examination of the data revealed that this correlation was significant only for males, more so for right-handed ones, although the difference between males and females on these correlations was not significant ($.10 < p < .05$).

One other interesting finding is the high positive correlation between scores on the RAT and the BWAS for non-righthanded females. If, as this finding suggests, this group is the least lateralized, it may be because they are female (Harris, Note 1; Harshman & Remington, Note 2) and non-right-handed (Hécaen & Ajuriaguerra, 1964; Hécaen & Sauget, 1971). If one views these tests as measures of lateralized skills, then there would be less interference among individuals who are not strongly lateralized. Thus, there is a high positive correlation for non-righthanded females and a negative correlation for righthanded males. However, this idea should be viewed cautiously, since the results for the females come from only five subjects.

TABLE 7

Correlations Between Score on the BWAS and the RAT

for Subgroups of the Ss Tested

	All Ss	Nonrighthanded Males	Nonrighthanded Females	Righthanded Males	Righthanded Females
r	-.286*	-.044	.799*	-.530**	-.231
N	72	7	5	35	25

* $p < .05$
** $p < .01$

DISCUSSION

While the reliability of judgment of direction of eye movements was lower than would have been desired, the results were in the predicted direction. In general, Ss looked to the right on verbal problems and to the left on spatial problems.

The purpose of this study was to examine the relation between creativity and hemispheric specialization. Models I and II consider creativity as a global ability associated with the right hemisphere (Model I) or both hemispheres (Model II). Models III and IV stress the importance of knowing the specific creative skill before considering which hemisphere is associated with it (Model III--right hemisphere for verbal, left for non-verbal; Model IV--vice versa).

The data in the current study do not clearly support any of these models. As on verbal problems, Ss looked to the right when solving creative verbal problems, i.e., those from the RAT. This suggests that a creative skill is associated with the same hemisphere as that skill (Model IV). But when subjects were grouped on creativity, as measured by the BWAS, those in the High group show less variation in eye movements than the Medium and Low groups. Those in the High group could be considered as more "middle," supporting the hypothesis that both hemispheres are involved in the creative process (Model II). However, the

failure to replicate these results when scores on the RAT are used suggests that knowledge of the creativity test used is important. Thus it appears short-sighted to look at creativity as an all-encompassing ability (Guilford, 1971).

How do the results of the current study square with other studies which have found creativity to be related to one or both hemispheres? One could point to the type of creativity test used, but most of these studies have used the RAT. Rather, the results of these studies may be due to two aspects of the testing procedure. In most studies, except for Hines and Martindale (1974), eye movements have not been recorded in response to creative problem solving. Instead an indirect approach has been used: subjects were classified as left or right movers. Then they were given a creativity test and the scores of each group were compared.

The second aspect of the testing procedure which may have affected their results is the position of the experimenter. Recall the proposal (Gur et al.,1975; Meskin & Singer, 1974) that when the experimenter faces the subject, the subject becomes anxious or has other difficulties in trying to solve the problem. Thus the results of the studies examining creativity and eye movements may indicate the preferred direction for looking by creative persons, rather than the cerebral hemisphere associated with creativity. The results from the current study, that when subjects were classified as High, Medium, and Low on creativity, no differences in direction of looking were found ,

do not contradict this. The creative person's preference for looking to the left may occur only when there is a person facing him (E-facing-S condition).

No sex differences were found in the current study, although there were some trends that support the hypothesis that females are less lateralized than males (Harris, Note 1). However these trends should be viewed cautiously.

All the correlations between problem type for direction of eye movement were positive, but only significant for females. This suggests that it makes less difference for females than for males what kind of problem is being asked. One could speculate that females are more likely to use similar processes in solving the problem, regardless of its type.

Secondly, there is a trend in the accuracy data that suggests that choice of direction was more likely to affect accuracy for males than for females. If females are less lateralized than males, then using the right hemisphere to solve a verbal problem, for example, would be expected more likely to produce accurate results for females than for males.

Another point of note in the current study was the negative relation between scores on the RAT and on the BWAS. Since the RAT measures a verbal skill and the BWAS an appreciation for drawings, the question can be stated as follows: Why does a high verbal ability correlate negatively with a preference for complex, asymmetrical drawings, at least for males? It is possible to argue that each test is examining different hemisphere

functions. But that only suggests that there should be no relation between the tests, not a negative one.

Creativity tests do have a reputation for low intercorrelations (Wallach & Kogan, 1965), but the correlations are usually positive. There is no obvious reason why in the current study the relation was negative. Further study is necessary. However, this finding does support the caution expressed earlier about globally categorizing creativity and trying to discover the hemisphere associated with creativity.

The idea of using creative questions directly to determine direction seems more appropriate than classifying subjects as left or right movers and comparing creativity scores. However, the use of RAT items may not be the best choice as a measure of creativity. One of the problems in examining creativity tests is the relation between creativity and intelligence. As has been pointed out by Wallach and Kogan (1962), many times creativity tests correlate better with intelligence tests than they do with other creativity tests. But if we are to talk about creativity with any meaning, it should be somewhat independent of intelligence.

The problem with the RAT is that it may depend too much on intellectual skill. Martindale (1975) has noted that the Alternate Uses Test may be a purer test of creativity, since it does not require so much intellectual skill as the RAT. A new study with RAT items replaced with those from the Alternate Uses Test would help to answer this question.

Martindale's (1975) study suggest further modification of the current study. He studied alpha waves among subjects of varying levels of creativity. To study which hemisphere or hemispheres are operating in the creative process, it might be useful to look at both eye movements and brain waves during problem solving requiring creative thought.

In summary, the current study has raised questions about the conception of creativity as a global ability. If creativity is a set of abilities, then it is futile to talk about the hemisphere or hemispheres associated with creativity unless all the abilities are associated with the same hemisphere(s), an unlikely event. Further studies will have to control more carefully the type of creative material present, if the neuropsychology of the creative process is to be understood.

APPENDIX A

Eye Movement Problems

Name _____ Sex: M F

Verbal Problems

1. Explain the proverb: "A rolling stone gathers no moss."
2. Spell "accommodate."
3. Explain the proverb: "A watched pot never boils."
4. Complete the following: Horse is to cavalry as foot is to _____.
5. Explain the proverb: "Rome was not built in a day."
6. Complete the following: Municipal is to city as national is to _____.
7. Spell "chauffeur."
8. Explain the proverb: "All that glitters is not gold."
9. Complete the following: Seldom is to never as most is to _____.
10. Spell "endeavor."

Spatial Problems

1. Imagine the map of the United States. In what direction is Chicago relative to Minneapolis?

2. Imagine you are standing in front of the library facing Beaumont Tower. In what direction must you go to reach Olin Health Center?

3. Visualize your library card. Where is your student number relative to your name?

4. Visualize sitting in front of a typewriter. Where is the letter "R" relative to "B"?

5. Imagine you are driving a car and approaching a triangular "Yield" sign. In which direction does the triangle point?

6. Visualize you are on the corner of Abbott and Grand River and you start walking toward M.A.C. Name one store you will pass on your way.

7. Imagine the campus as a clock with the Men's IM at the center and the Administration Building at 12 o'clock. In what hour approximately will the Union Building be?

8. Imagine a map of the Great Lakes area. Above what state is the western part of the upper peninsula in Michigan?

9. Visualize sitting in front of the typewriter. Where is the letter "D" relative to "O"?

10. Visualize a telephone dial. Where does the area code appear relative to the number?

Creative Problems

1. Find the fourth word that is related to these three:

   athlete's web rabbit

2. Find the fourth word that is related to these three:

   mouse sharp blue

3. Find the fourth word that is related to these three:

   stop petty sneak

4. Find the fourth word that is related to these three:

   note dive chair

5. Find the fourth word that is related to these three:

   envy golf beans

6. Find the fourth word that is related to these three:

   elephant lapse vivid

7. Find the fourth word that is related to these three:

   board magic death

8. Find the fourth word that is related to these three:

   soap shoe tissue

9. Find the fourth word that is related to these three:

   bald screech emblem

10. Find the fourth word that is related to these three:

    chocolate fortune tin

APPENDIX B

Remote Associates Test Form B

Name _____ Sex: M F

Instructions: In this test you are presented with three words and asked to find a fourth word which is related to all three. Write this word in the space to the right.

For example, what word do you think is related to these three?

cookies sixteen heart _____

The answer in the case is "sweet." Cookies are sweet; sweet is part of the phrase "sweet sixteen" and part of the word "sweetheart."

Here is another example:

poke go molasses _____

You should have written "slow" in the space provided. "Slow poke," "go slow," and "slow as molasses." As you can see, the fourth word may be related to the other three for various reasons.

Try these next two:

A. surprise line birthday _____

B. base snow dance _____

The answers are on the bottom of the page. Now turn to the next page and try the groups of words on the inside. Many of these items are not easy and you will have to think about some for a while. If you have trouble with some group of three go on to the next and come back later. Give only one answer to each question. You will have 20 minutes.

Answers: A. party; B. ball

1. finger diamond friendship _____
2. speak money street _____
3. worm red ticker _____
4. beat town fourth _____
5. barrel root belly _____
6. hall car swimming _____
7. stick light birthday _____
8. plain Tarzan Dick _____
9. heigh-ho quick spoon _____
10. falling dust general _____
11. soda kilt butter _____
12. whistle cry timber _____
13. bug drill hell _____
14. girl social bugle _____
15. cloth sad out _____
16. folk bird swan _____
17. head herring underwear _____
18. pig steam mask _____
19. off trumpet atomic _____
20. cotton bathtub tonic _____
21. home grant low _____
22. dry head collar _____
23. foot collection out _____
24. ticket shop broker _____
25. out party mother _____
26. motion round tennis _____
27. blue mark club _____
28. bag dream bubble _____
29. sandwich ball foot _____
30. high book sour _____

APPENDIX C

Handedness Questionnaire

Name _____ Sex: M F

Questionnaire On Hand Preference

First, state whether you regard yourself as right-handed (R), left-handed (L) or ambidextrous (A) _____ General Instructions: The main body of the questionnaire falls into two parts:

Part A is designed to find out which hand you habitually use, or would prefer to use, for certain acts requiring the use of one hand only. It is expected that habitual tendency and preference will, for the most part, coincide, but if there is any case where they differ, you are asked to add a note to that effect.

Part B is designed to find out which hand plays the leading role in certain acts requiring the use of both hands. Indicate in the column provided R, if you use your right hand, L, if you use your left hand, or E, if you are aware of no special preference in either direction, i.e. if you are just as likely to use one hand as the other. When in doubt, you should try to settle the issue by experimenting, for example, by going through the motions or by trying to visualize yourself performing the action.

Part A

1. With which hand do you throw? _____
2. With which hand do you write? _____
3. With which hand do you draw? _____
4. With which hand do you play games such as tennis, squash, badminton, and paddle ball? _____
5. With which hand do you use a pair of scissors (e.g., for cutting paper)? _____
6. With which hand do you use a razor? (state type of razor) _____
7. With which hand do you use a comb? (state side on which you part your hair) _____
8. With which hand do you use a toothbrush? _____
9. With which hand do you use a knife for purposes other than eating? (e.g. cutting string, sharpening a pencil) _____
10. With which hand do you use a spoon for eating? _____
11. With which hand do you use a hammer? _____
12. With which hand do you use a screwdriver? _____

Part B

13. With which hand do you use a knife for cutting, in conjunction with a fork? _____

14. On which side of your body do you swing a baseball bat? _____

15. On which hand do you hold the top of a broom when sweeping? _____

16. With which hand do you unscrew the lid of a jar? _____

17. With which hand do you hold the top of a rake when raking? _____

18. With which hand do you strike a match? _____

19. With which hand do you deal cards? _____

20. With which hand do you guide the thread through the eye of a needle, or the needle onto the thread, as the case may be? _____

APPENDIX D

A Multidimensional Scaling Examination of the Eye Movement Questions

One aspect not considered in the body of the current study is the questions used to elicit conjugate lateral eye movements. To date there has been no standardization of the problems used in eye movement studies. Indeed Gur et al.(1975) reported that Kinsbourne (1972) used problems which did not require any verbal response.

The concern here is to provide some bases for evaluating the types of problems used in eye movement. This will involve finding those verbal and spatial problems which elicit eye movement patterns distinct from each other.

Since multi-dimensional scaling programs need a similarity matrix as input, one was calculated in the following way. Subjects could look to the right, to the left, or their direction of eye movement could not be determined. Assuming that if a subject moved his eyes in the same direction on two problems these problems were somewhat similar, a matrix of co-occurrence was calculated for each subject. A one was placed in a specific cell if the subject looked in the same direction on the two problems, otherwise, a zero was placed in that cell. (Questions in which the direction of eye movement was missing for the subject were not compared.) The matrices for all 40 subjects were then added together.

Since there were 40 subjects in the experiment, the maximal level of similarity would be 40, the minimal 0. Random similarity should be 20, since there were only two directions in which the subjects could look. However, because of a general tendency to

look to the right, the average similarity score was somewhat higher (approximately 23). The range of these similarity scores was from 12 to 34.

The combined matrix was input to KYST, a multidimensional scaling program which plots data as points in some n-space in such a way that distance between points is indicative of their similarity. Several random runs produced similar plots of the data. Figure 2 shows the final configuration which had the least stress--.208. The notation of the points stands for the type and number of the problem. For example, S_7 means the seventh spatial problem.

Attempts at clustering these points using the HICLUST program and at examining the similarity between subjects by the KYST and HICLUST programs produced uninterpretable results. Hence they will not be discussed.

Interpretation of the Scaling Solution

The configuration in Figure 2 is interpretable. The X-axis appears to be a continuum of verbal to spatial, with all the spatial problems to the right of the origin. This finding lends support to the point emphasized in the body of the current study that subjects react in similar ways to a distinct set of questions yet in quite distinct ways when comparing spatial with verbal questions.

The first question of concern was which spatial problems were strongly distinguished from verbal problems. As can be seen in Figure 2, the spatial problems appear for the most part

Figure 2

[illegible] Representation of Similarity of 30 Problems Used to Elicit

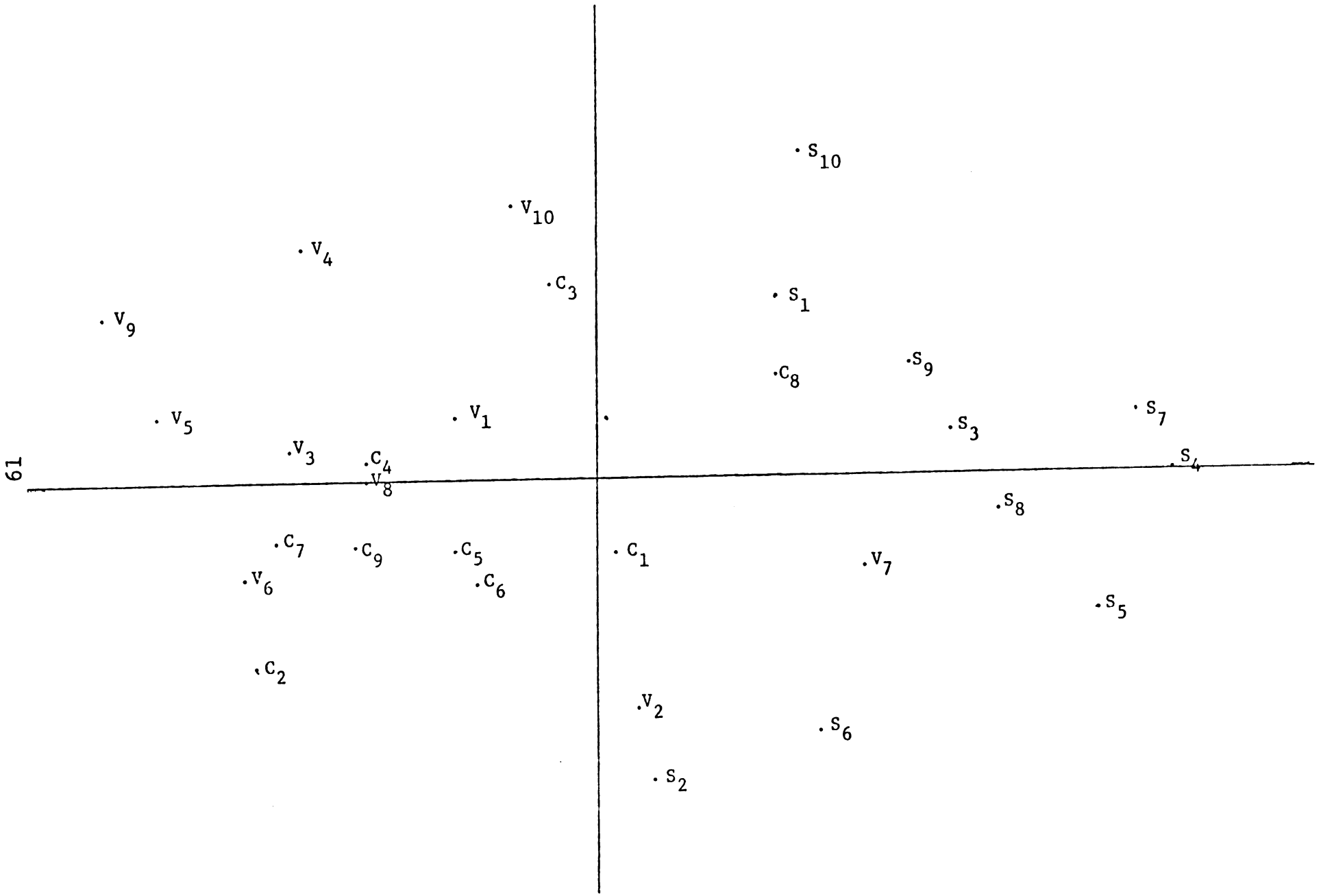

Figure 2
Spatial Representation of Similarity of 30 Problems Used to Elicit
Conjugate Lateral Eye Movements

homogeneous. But S_2 and S_6, which are closer to the origin than most spatial problems, are of the type "Imagine yourself in this situation...", while others are of the type "Where is...?" However, before one makes too much of this pattern, it should be noted that two problems involving locating letters on a typewriter (S_4 and S_9) are moderately far apart.

When comparing creative and verbal problems there is less distinction. In fact, the highest similarity score was obtained between a verbal problem and a creative problem (V_8 and C_6). This may be due to the problem mentioned in the body of the current study, that the Remote Associates Test is a verbal test.

However, closer examination of the verbal and creative problems reveals a basis for distinguishing verbal problems from spatial problems. The verbal problems are more spread out than the creative problems, not surprising since all the creative problems came from the Remote Associates Test, while the verbal problems came from a variety of sources.

A pattern emerges from these sets of verbal problems. Those problems (V_2, V_7, V_{10}) closest to the spatial problems are all spellings. This is not surprising if one reasons that when trying to spell a word, a person forms a spatial representation of the letters of the word and then determines if this picture looks right. The proverb explanations (V_1, V_3, V_5, V_8) and the analogies (V_4, V_6, V_9) are more clearly distinguished from the spatial problems.

If one eliminates the spellings, a clearer distinction can be made between the creative and verbal problems. The spatial and verbal problems appear at the opposite extremes of the plot with the creative problems in the middle, a little closer to the verbal than the spatial.

The second dimension (Y-axis) in Figure 2 appears to be a difficulty continuum. For example, remembering where the area code appears on a telephone dial (S_{10}), above the origin, seems easier than tracing the path from Beaumont Tower to Olin Health Center (S_2), below the origin.

This multidimensional scaling suggests that, if we wish to use spatial and verbal problems that are distinct from each other in eye movement studies, one should include "Where is...?" and exclude "Imagine yourself in this situation..." in spatial problems and include analogies and proverb explanations and exclude spellings in verbal problems.

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