IMAGERY AND CONJUGATE LATERAL EYE-MOVEMENT

by

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ABSTRACT

Two studies are reported that were designed to assess the hypothesis that asymmetries in conjugate lateral eye movement (CLEM), defined operationally as the direction of the subject's initial gaze shift following presentation of a problem for solution, are related to specialization of function of the cerebral hemispheres, such that CLEMs constitute an index of the relative initial involvement of the hemispheres during information processing.

The first study looked at differences in long term free recall, between groups formed on the basis of predominant direction of initial gaze shift following presentation of twenty questions designed to elicit eye movements. Right-moving and left-moving groups were compared under three separate sets of instructions as to the strategy (interactive imagery, verbal associative linkages, or subjectively derived mediators) to be used in remembering abstract, as well as concrete, noun triplets. The finding that right-movers were superior at utilization of interactive imagery mediation instructions was contrary to expectations based on the above mentioned hypothesis.

A second study using correlational and factor-analytic techniques was done to further investigate the relationship between CLEMs and performance on objective tests related to visual imagery, as well as subjective ratings of imagery vividness and control. CLEMs were found to be significantly related only to a factor defined by performance on objective tests related to visual imagery. The direction of the correlation indicated that right-movers performed more effectively on these tests.

The results of the two studies are discussed with respect to the hemispheric specialization hypothesis, and alternative theoretical formulations that might account for these findings.

I would like to offer my appreciation to Vivian, who gave up a great deal in support of this effort; and to Dr. Paul Bakan who provided the space and nurturance to allow it to happen.

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Conjugate Lateral Eyemovement Phenomenon

It has been noted for some time, that a person who is asked a question that requires some consideration in order to formulate an answer, will look away to one side of the questioner while developing the response. This behavior has been termed conjugate lateral eye-movement (CLEM) by Bakan (1969,1971). An early hypothesis with regard to this behavior maintained that it reduced visual interference, facilitating concentration on the problem at hand (Bramwell, 1927, cited by Bakan, 1971).

Day (1964,1967a,1967b,1968) made further observations of this activity in a clinical setting and found that the direction in which the person looks is characteristic for the individual. He thought that this behavior dichotomized the population into right-movers and left-movers according to the predominant direction of looking, during reflection on a number of questions. He found several correlates of eye-movement direction and theorized that it was related to typical patterns of attentional distribution. He described right-movers as externally-oriented visual attenders who experienced anxiety as a feeling of panic accompanied by cholinergic autonomic sensations. Left-movers on the other hand, were seen as internally oriented attenders who experienced anxiety as tension accompanied by adrenergic autonomic sensations. He also felt that this dichotomy was related to language acquisition and usage such that right-movers were disposed to use verbs, while left-movers tended to use more descriptive language, including many adjectives.

Duke (1968) confirmed Day's observations concerning the consistency of eye-movements in a laboratory setting. He found that within subjects, approximately 85% of an individual's eye-movements were in one direction. He also noted that more difficult questions were more likely to elicit eye-movements, that males were more consistent than females, and that there was no sex related tendency to look in one direction or the other.

Studies done to assess the reliability of CLEM behavior (Bakan and Strayer, 1973; Etaugh and Rose, 1973; Libby, 1970) have found correlations in the upper .70's for test-retests over periods of time ranging from a few hours to two weeks. Interobserver agreement on the scoring of CLEMS was reported to be in the high .80's and low .90's.

Bakan (1969) noticed the similarity between Day's (1964) description of the left mover and Hilgard's (1970) description of the good hypnotic subject as "one who has rich subjective experiences...one who is interested in the life of the mind...and one who accepts impulses from within." Bakan administered the Stanford Hypnotic Susceptibility Scale to a group of college students and also determined their predominant eye-movement direction in response to a set of questions. He found, as expected, that left-movers had significantly higher hypnotic susceptibility scores. They also reported more vivid visual imagery, scored relatively lower than right-movers on a test of mathematical ability, and were less likely to be majoring in mathematics or "hard" science areas.

Day (1967a) had looked at EEG records of right- and left-movers and determined that left-movers showed greater amplitude and lower frequencies of activity than right-movers.

This, taken with findings (Nowlis and Rhead, 1968) that related incidence of alpha activity to hypnotic susceptibility, led Bakan to the investigation of the relationship between lateral eye-movements and alpha waves (Bakan and Svorad, 1969). He found that left movers had baseline alpha 52% of the time compared with 20% for right-movers.

This study was replicated and extended by Strayer (1971). He found that males who had high basal levels of alpha were more likely to be left-movers. Left-movers were also able to increase their alpha production in a bio-feedback training task, Regardless of whether the feedback was "real-time" or from yoked controls.

Bakan (1969,1971) theorized that underlying the consistency in findings with respect to left- and right-movers, is a relationship between the direction of typical eye-movements and the ease with which one or the other hemisphere is "triggered" for information processing functions. He noted reports that stimulation of the frontal eyefields (Brodman's area 8; Robinson, 1968) results in eye-movement to the contralateral side of stimulation. He concluded that the lateral eye-movement phenomenon could be indicating that the individual was preferentially using the contralateral cerebral hemisphere. He felt that one or the other hemisphere might be more readily activated as a consistent characteristic of a given person.

Other investigators reasoned that if CLEMs were related to the hemisphere being used to process information, it might also be the case that the nature of the task given the person to process might influence which hemisphere was used for processing, so that in addition to an individual tendency to use one or the other hemisphere there might also be some task related variance in CLEMs. A series of studies was run inquiring into the effect of the nature of the questions asked the subject, on his subsequent eye-movements (Ehrlichmn, Weiner and Baker, 1974; Galin and Ornstein, 1974; Gur, Gur and Harris, 1975; Kinsbourne, 1972,1974; Kocel, Galin, Ornstein and Merrin, 1972; Bakan, Coupland, Glackman, and Putnam, 1973). For the most part, these investigators relied on very general ideas about the right hemisphere being specialized for parallel visuo-spatial processing and the left hemisphere for sequential verbal processing, and formulated questions that were supposed to be more readily processed by a particular hemisphere with "spatial" questions for the right and "verbal" questions for the left. There was a great deal of subjectivity involved in the production of these items and conflicting reports resulted with respect to their effect. As a result of this the issue with regard to the relationship between CLEMS and hemispheric specialization was obscured.

Bakan et al (1973) attempted to sort this out by utilizing items from several of the above studies in a design that allowed the effect of subject and question type to be separated. They found that indeed there was an effect due to question as well as to the individual, but that the latter accounted for twice as much variance as the former. It also became apparent that there was not any simple way to categorize questions with respect to the direction of their influence on eye-movements, on the basis of content alone. From this study they developed a set of questions that appeared to be relatively "neutral", in the sense that they did not show any average tendency to influence eye-movement direction in a college student population. These were then available for use in further studies of individual preference for eye-movement direction.

Hemispheric Specialization

Hemispheric specialization is a term used to designate one particular form of function localization theory. The distinguishing characteristic of this concept is the idea that the cerebral substrate of a particular psychological function or group of functions is located in one, but not both, of the cerebral hemispheres. This idea has been around a long time, and probably originated with the first person to notice the clear anatomical distinction between the cerebral hemispheres, coincident with their nearly perfect mirror image duplication of each other. One could easily conclude that there are two brains resident in the cranium, and additionally infer that they subserve different purposes. This form of conjecture was made explicit by Wigan (1844) among others. He wrote a book proposing that there is a separate "personality" in each hemisphere and that much of the polarization in human affairs is a result of conflict between the two for control of the complete psychological system.

Information accumulated from brain damage cases was not inconsistent with a hemispheric specialization hypothesis. It was observed that certain kinds of malfunctions occurred following damage to a particular side of the head. Most notably various kinds of speech difficulty followed injury to the left side, while problems with spatial orientation appeared to be related to right side damage. The relationship between deficit and injury remained obscure, however, because of a lack of understanding of confounding variables that has only lately begun to be worked through.

Data that support the theory of hemispheric specialization have recently come from research done in conjunction with the treatment of brain pathology and also from studies of normal individuals utilizing methods designed to reveal processing differences between the two hemispheres.

A number of different methods have been used in work with individuals suffering from some degree of brain malfunction. The most spectacular of these, and the one that has perhaps offered some of the clearest information about the nature of the functions resident in each cerebral hemisphere, is the so-called "split-brain" technique used by Bogen (Bogen and Vogel, 1962) and studied by Sperry and his associates (Sperry, Gazzaniga and Bogen, 1969).

The split-brain technique applied to humans is more properly labelled a commissurotomy, and involves cutting some portion of the nerve fibers (cerebral commissures) that connect the two halves of the brain. This is a modification of the true split-brain preparation used by Myers (1957,1962) in studies utilizing cats.

In the true split-brain procedure the optic chiasm is cut, as well as the commissures. This results in an animal in which the information provided by each eye is restricted to the hemisphere on the same (ipsilateral) side. Covering the eyes selectively during training, it could then be shown that learning could be confined to one or the other hemisphere. In fact different responses to the same stimulus could be programmed into each hemisphere. These studies did not, however, provide evidence of differential capabilities between the hemispheres. Split-brain studies with monkeys (Trevarthen, 1964) further established that there were relatively independent functional capabilities and memory systems in each hemisphere, and showed that the animal could function adequately in the deconnected state, but again didn't offer evidence of differential processing capacities between the two hemispheres. Clear evidence of hemispheric specialization was not to come until studies were done with humans who had been commussurotomized and tested under special conditions.

Understanding the distinction between a split-brain preparation and a commissurotomy is crucial, if one is to understand the need for special methodology to detect and assess the effect of this operation on humans. As mentioned above, in the former procedure the optic chiasm as well as the commissures are cut, while in the latter only the commissures are severed, and in the most recent variations (Gazzaniga,1974) only specific sections of the commissures are cut. The functional difference between the former operation and the latter is that instead of the visual information from each eye being restricted to a single hemisphere as in the split-brain preparation, both hemispheres are receiving information from both eyes. However, due to the structure of the optical nerve tracts, each hemisphere is receiving input from only one visual half-field. This is also the case in normal individuals but the visual information from the other half-field is available to both hemispheres via the intact commissures. It is this specific type of information i.e. from the ipsilateral visual half-field, that is not available to each hemisphere in the commissurotomized individual. This does not create any great practical difficulties for the patient, as in most everyday situations a person is free to make eye-movements and scan the visual scene before him, thereby providing similar data to both hemispheres. In fact, the specific effects of this operation are quite difficult to detect. The operation was done by Akelaitis (1941,1942,1944), before much of the current information was available, and he concluded that the procedure had little effect on the capabilities of his patients.

As mentioned above, special arrangements must be made to reveal the effects of a commussurotomy. The intact optic chiasm makes it insufficient to simply cover one eye in order to restrict information flow to a single hemisphere. It is necessary to restrict information to the contralateral visual half-field if one wants to ensure that it is available to only one hemisphere. The most common way to do this is to project it to one side of the visual fixation point for a duration that is too short to allow eye-movements to occur. Similar kinds of restriction of information to sensory receptors on the contralateral side of the body from the hemisphere that is to be informed, allows testing of other input modalities, in particular the haptic and auditory systems.

Research done under the appropriate conditions (Sperry, 1968; Sperry et al, 1969; Bogen, 1969a,1969b,1969c; Levy et al, 1972; Nebes, 1971, 1974) has shown that the left hemisphere is specialized for language functions and arithmetical calculation, and that its processes are best characterized as analytical, logical, sequential and symbolic. The right is capable of doing tasks involving perception of complex spatial patterns and part-whole relationships, music, and recognition of human faces. Its processes may be characterized as being synthetic, parallel, visuo-spatial and imaginal.

A particularly outstanding finding has been the apparent dissociation of consciousness between the disconnected hemispheres, a kind of vindication of Wigan's ideas, and in the same context, evidence of the capacity for cooperation between them (Sperry, 1968). Since the normal pathways for internal communication were cut, it was possible to observe the more capable hemisphere system for a particular task attempting to "help out" and improve the response of the less capable during testing, indicating that the capacity exists in each hemisphere for higher level integrative and executive functions involving the organization and utilization of the special capabilities of each side for the performance of relevant tasks. Conversely, different emotional states were seen to be expressed by the two sides after selective projection of titillating stimuli in the half-fields, indicating the separation of awareness present in these cases.

Studies of the relative capabilities and specializations of the two hemispheres have also been done with normal subjects, using EEG techniques (Galin and Ornstein, 1972), evoked potentials (Galin and Ellis, 1975), and half-field projection techniques using various dependent variables (Rizzolatti, Umilta and Berlucchi, 1971; Kimura, 1966,1969; Seamon and Gazzaniga, 1973).

Galin and Ornstein (1972) found relatively higher alpha (taken to indicate "idling" or decrease in activation) over the right hemisphere during verbal tasks and relatively more alpha over the left hemisphere when the subject was engaged in a spatial task. Galin and Ellis, (1975) noted changes in the asymmetry of evoked potentials as subjects were switching from verbal to spatial tasks, that paralleled the findings from the alpha production study.

Rizolatti, Umilta and Berlucchi (1971) presented letters or pictures of faces in the visual half-fields and recorded reaction times for positive and negative instances of previously learned relationships. They found that the verbal stimuli were responded to fastest with presentation to the left hemisphere, and shortest reaction times for the faces, with presentation to the right hemisphere.

Seamon and Gazzaniga (1973) had subjects learn pairs of nouns in a short-term recognition memory task, using either relational imagery or rehearsal coding. Relational imagery is a mediation technique used by Bower (1972) which consists of instructions to form a composite visual-imaginal scene containing the objects representing the items to be remembered in such a way as to be touching, or in contact with, each other. They found that reaction times were fastest for probes to the left hemisphere when rehearsal was used and quicker for probes to the right hemisphere when imagery coding was used.

Individual Differences and Hemispheric Specialization

Given that it has been sufficiently established that there are subsystems contained within a cerebral hemisphere that can carry out functional operations without the involvement of the other hemisphere in deconnected organisms, the question of real interest revolves around the extent to which this is the case in normal, hemispherically connected individuals. One would expect that rarely if ever, would a task require psychological functions involving subsystems located in one hemisphere to the total exclusion of the other. The presence of functioning commissures would at the very least seem to suggest that the other hemisphere would be receiving information from the active side that would inhibit interference, so that at least to that extent, both hemispheres could be said to be involved in any particular processing event.

Beyond that, is it reasonable to believe that given a task that is amenable to different approaches or methods of solution, particular individuals will utilize particular methods, methods that depend wholly or partially on subsystems based in one or the other hemisphere, and that these are characteristic for that individual?

As noted above, there have been a number of studies using normal subjects showing that one or the other hemisphere is "better" at processing particular kinds of tasks. (The specific meaning of better is of course dependent on the conditions of the particular study.) These have involved tasks that were known or thought to be particularly relevant to the subsystems of a specific hemisphere and were thereby not suited for answering the question of interest about tasks that could be processed by subsystems from either or both hemispheres. A set of studies by Hellige (1975) using eye-blink conditioning has provided evidence that is relevant to this question.

He was investigating the factors underlying the different types of classical conditioning response given by so-called V- and C-form responders in an eye-blink conditioning paradigm. The V-form response is a relatively rapid, more complete eyelid closure of longer duration and earlier onset than the C-form response.

His first study sought to determine the differential response of C's and V's to the semantic aspects of visually presented stimuli projected directly to the left and right cerebral hemisphere via the visual half-field on the contralateral side. He interpreted his results to indicate that the conditioning performance of C's is normally less mediated by left-hemisphere processing than that of V's.

A second study looked at the differences between C's and V's on two reaction time tasks, the first requiring the subject to indicate whether an uppercase letter had the same or different name as a lower case letter, and the second requiring a same/different response with respect to the shapes of two low-verbalizable polygons. Tasks similar to the first have been previously shown to be more effectively performed with right visual field (left hemisphere) presentation (Geffen, Bradshaw and Nettleton, 1972) and ones like the second with left visual field (right hemisphere) presentation (Dee and Fontenot, 1973). Again Hellige felt the results suggested that C-form responders do not typically utilize left hemisphere processing capability. Hellige (1975, p. 323) concludes from these two studies that "C's seem to prefer visuo-spatial aspects of processing while the V's seem to prefer abstract, verbal aspects of processing."

These studies would seem to indicate that it is possible to demonstrate individual differences in normal subjects that are related to hemispheric specialization, on so-called "neutral" tasks that can be solved with methods based on the capabilities of either hemisphere; and following that to further identify information processing pecularities of groups formed on the basis of these individual differences.

In light of the evidence from different sources mentioned above that relates imaginal, visuo-spatial functions to the right hemisphere, and indicates more vivid visual imagery on the part of left-movers, further investigation was undertaken of functions presumably mediated by the right hemisphere, utilizing subjects whose characteristic eye-movement direction was also ascertained. Two studies were planned. The first involved a comparison of types of mediation instructions (interactive imagery, verbal associative and control) to be used to remember abstract and concrete noun triplets in a long-term memory free recall paradigm. The second looked at performance on a number of measures previously related to various aspects of visual imagery ability, including subjectively rated vividness and controlability, and objective paper and pencil tests of spatial abilities.

Rationale for Study I

A study was designed to look at the differences between right-movers and left-movers with respect to two different kinds of variables that have been linked to hemispheric specialization, used as independent variables in a long term memory (LTM) free recall task.

The first set of variables involved the kind of coding instructions given to the subjects in the LTM task. As mentioned above, Seamon and Gazzaniga (1973) established in a short term memory task that cerebral laterality effects are related to coding strategies such that the right hemisphere yielded shorter latencies than the left in a same-different reaction time paradigm when subjects used interactive imagery coding instructions, and just the opposite when they used rehearsal coding. However rather than use imagery vs rehearsal coding as they did, it was felt that it would be more informative to use a "constructive" task of forming words or phrases as mediating links among the to be remembered words as Paivio and Yuille (1967) had done. It was hoped that this would be more comparable to the task involved in the imagery coding instructions of forming an interactive, unified imaginal scene. An uninstructed control group was also included in order to observe differences between the two eye-movement groups resulting from any typical information processing proclivities that might exist.

Another set of variables was included based on the two-process theory of Paivio (1969,1971). He maintains that there are two separate verbal processing systems in the brain, one responsive to the abstract, semantic aspects of words and the other, utilizing visual subsystems, responsive to the concrete, visuo-spatial, imaginal aspects of words. He has shown a number of effects substantiating his theory, utilizing materials that have been scaled on the abstract/concrete dimension (Paivio, Yuille and Madigan, 1968). It has been suggested (Bower, 1970; Paivio, 1971; Seamon and Gazzaniga, 1973) that these systems might be functionally discriminated along hemispheric lines with the former resident in the left hemisphere and the latter in the right. It was therefore decided to include both abstract and concrete nouns among the to be remembered words used in the memory study.

What predictions would be made with respect to right-mover/ left-mover differences pertaining to these variables? Once again the asumptions are: 1) that right-movers are predisposed to process information via the left hemisphere, while left-movers prefer the right hemisphere; 2) imagery coding is a right hemisphere function and verbal coding is a left hemisphere function, while no instructions as to mediation method should allow subjects to express their "natural" preference with respect to coding; 3) there is a visual /imaginal encoding system based in the right hemisphere which is more effective with concrete nouns than abstract nouns and a semantic/verbal encoding system resident in the left hemisphere that is capable of dealing equally well with abstract and concrete nouns.

One would then expect left-movers to perform better than right- movers under imagery coding instructions, and right-movers to perform better than left movers under verbal instructions. Given the opportunity to select their own mediation strategies, subjects should adopt that most closely related to their hypothesized typical hemisphere, namely, right-movers were expected to spontaneously adopt verbal coding strategies and left-movers to adopt imaginal strategies. Right-movers should out perform left-movers with abstract words. One component of a three-way interaction should find that under the condition of no mediation instructions, right-movers are better than left-movers with abstract words and that left-movers are better than, or equal to, right movers with concrete words.

It is uncertain whether left-movers would be expected to excel over right-movers with concrete words or simply equal their performance, as the left hemisphere encoding system proposed under the two-process theory is supposedly equally capable of processing abstract and concrete nouns, but it is unclear whether processing of concrete nouns in the left hemisphere is more or less effective than processing them in the right hemisphere. It might also be that right-movers would outperform left-movers with concrete words as they may dual encode them in both hemispheres, and thereby have a better chance of recalling them.

METHOD

Subjects

Subjects were 73 right-handed male volunteers who had filled out a card (distributed in Simon Fraser University undergraduate psychology classes) indicating that they were interested in participating in psychological studies. They were subsequently contacted by telephone and an appointment was arranged. They received $2.00 for their participation in this study.

Subjects who made lateral eye-movements in response to 80% or more of the twenty questions and whose eye-movements were 70% or more in one direction, were scheduled for the memory study.

At this point there were 32 left-movers and 33 right-movers who conformed to all criteria. They were placed in random order within eye-movement groups and assigned in blocks of ten to instruction conditions. The two left-movers and three right-movers remaining were contacted and told it would not be necessary for them to keep the second appointment.

Apparatus

During the first part of the study a Sony Portapak camera and recorder were used to videotape the eye-movements of the subjects. This system was controlled by a footswitch on the floor hidden from sight by a desk.

In the memory portion of the study, stimulus control was provided by a Tally eight channel paper tape reader initiating Grason-Stadler timers and relays. Paper tapes were punched by a Hewlett-Packard computing system.

Latency of mediator acquisition was recorded by a Hunter Model 145 print-out counter as the number of pulses of known repetition rate generated by a Hunter Model 157 timer.

Subjects sat in an IAC Model 11170 soundproof booth throughout the memory portion of the study. Stimuli were back projected on an opaque screen mounted on the window of the booth. A series of lights mounted in a horizontal row directly below where the stimuli were projected provided subjects with sequencing information.

Subjects' verbalizations were recorded on a Uher 2400 Stereo Report tape recorder during the long term memory recall period.

Materials

The twenty questions (Appendix A) were taken from a prior study (Bakan, Coupland, Glackman and Putnam, 1973) which scaled a variety of questions with respect to their tendency to elicit lateralized eye-movement. Twenty questions were used that were "neutral" in the sense that they did not show any average tendency to elicit eye-movements predominantly in one direction or the other in a sample of right-handed male university students similar to those participating in these studies.

The nouns used in the memory study were taken from those scaled by Paivio, Yuille and Madigan (1968) on the attributes of concreteness, imagery and meaningfulness. Two groups of words were formed. 75 were selected that were high on concreteness and imagery, along with 75 that were low on these attributes. All words had fewer than six letters. The two groups were roughly equivalent on meaningfulness and Thorndike-Lorge frequency. The mean values of the different attributes for the two groups were respectively: 6.72 and 2.21 for concreteness; 6.48 and 2.82 for imagery; and 5.98 and 5.46 for meaningfulness. Within groups, the words were randomly formed into 25 triplets under the constraint that no triplet have more than one word with six letters. Each triplet was then made into a slide.

The readings used in the period prior to the long term recall of each block were taken from articles in a book of readings for an introductory psychology course (Wertheimer, 1970).

The post-study interview consisted of a listing of 2 randomly selected abstract and concrete noun triplets from each block. The experimenter questioned the subject about the mediator he had used for these particular words and marked down whether it was verbal, imaginal, rote repetition, none, or some other kind of mediator, after the method of Paivio and Yuille, (1967).

Procedure

During the eye-movement recording phase of the study, subjects were seated across a desk from the interviewer. Directly behind and above the interviewer's head was a video camera supported by a tripod. Subjects were told that the study was intended to relate cognitive processes during problem solving with performance in an experimental task. They were told that the problems they were to be given could in some instances be solved in a number of ways and that there was no single correct answer. The interviewer read each of twenty questions (Appendix A). Just before the end of each question he activated the video recording system with the foot switch. The interviewer was careful to present each question in such a way as to be looking directly into the eyes of the subject at the end of each question. He then noted the direction of the subject's first eye-movement after the end of each question, as a number from 1 to 12, indicating the direction of the movement on an imaginary clock face superimposed around the subjects' eyes. A line drawn horizontally through the eyes was taken to represent the "9 o'clock" to "3 o'clock" axis, regardless of the tilt of the subject's head. When the subject had completed his response, the interviewer said "O.K." and placed a checkmark after the question on the numeral representing the clock face direction of the subject's first eye-movement. This was done in such a way as to maximize the possibility that the subject would interpret this activity as the interviewer checking off the question just asked.

During the memory portion of the study the participants were taken to a laboratory which contained two soundproof booths and racks holding timing equipment, where they were seated in one of the soundproof booths. Then they received instructions (Appendix B) pertaining to the experimental procedure and the particular mediator they were to utilize to remember the words. There were three mediator groups: the control group which was free to utilize a mediator of their own choosing; the imagery group who were told to form an interactive imaginal scene (Bower, 1972) in which the images designated by the nouns were in contact with each other; and a verbal group who were told to connect the nouns with verbal links in order to form a verbal unit.

All groups experienced the same experimental procedure. They were presented with five blocks of ten trials each. The first block was considered practice and was not included in analysis. On each trial the subject saw a warning light, then three nouns projected for three seconds, followed by a fifteen second blank period when he was to apply the mediator, pressing a hand-held button to indicate acquisition of the mediator, then continuing to consider the mediator until the end of the period. Next came a three second short term memory recall light at which point the subject recalled aloud the words he had seen on that trial. The experimenter noted whether he had correctly recalled the words, and the warning light came on to begin the next trial.

At the end of ten trials, a light came on for thirty seconds, during which time the subject read aloud from the materials provided. Then the long term memory light came on and he had five minutes to recall aloud the words he had seen up until that time. At the end of that period another block started. This sequence was repeated for a total of five blocks.

Half of the slides in each block had concrete words and half had abstract words. Blocks of slides were rotated so that each block appeared equally often in each of the five positions. Within blocks slides were initially placed in random order and then subsequently rotated so that each slide appeared equally often in each position within a block.

At the end of the recall period following the fifth block E entered the booth and administered the post-study interview, debriefed and payed the subject.

RESULTS

Conjugate Lateral Eye-movement Measure

The video tapes were viewed by a second trained rater who also recorded the clock direction of the subjects first eye-movement after the end of each question. The Pearson r correlation between the two ratings was .77 ($N=65$, $p <.01$). The differences in ratings by the two judges did not in any case change the eye-movement group to which an individual had been assigned by the initial rating, or bring him below the criteria stated above with respect to total number of eye-movements and percentage of directionally consistent eye-movements.

STM Recall Data

A short term memory recall period was included primarily as a way to check and control for the accuracy of perception and other input stages of processing. Due to ceiling effects (there were only 2% errors in STM recall throughout) the recall data from this stage were not further analyzed. No one gave a "can't do it" response to indicate that they were unable to comply with their mediation instructions.

LTM recall data

The data were scored in terms of the number of triplets and the number of single words of each type recalled from a particular block, during the LTM recall period following that block. Preliminary analysis indicated a floor effect for the triplets variable so it was excluded from further analysis.

The number of words recalled was analyzed with a UCLA Biomedical Programs analysis of variance, BMD08V (Appendix C).

There was a significant main effect of instruction type, $F(2,54)=29.73$, $p<.001$. Neuman-Keuls post-hoc analyses indicated that imagery instructions ($M=4.3$) were significantly more effective than verbal instructions ($M=3.7$), $p<.01$, which were in turn significantly more effective than free instructions ($M=3.3$), $p<.01$.

There was a significant main effect for eye-movement type $F(1,54)=7.49$, $p<.01$. Indicating that right-movers ($M=3.9$) were slightly more effective than left-movers ($M=3.6$).

There was a significant main effect of word type, $F(1,54)=40.01$, $p<.001$. Concrete words ($M= 4.1$) were recalled better than abstract words ($M= 3.5$).

There was a significant interaction of eye-movement type and instructions, $F(2,54)=4.97$, $p<.01$. Percent recall for each eye-movement type under the three instruction conditions is shown in Figure #1, indicating principally that right-movers showed better recall than left-movers under imagery instructions.

Finally, there was a significant interaction of instruction type and word type, $F(2,54)=8.57$, $p<.001$. Figure #2 shows this relationship with concrete and abstract words being recalled about equally well under verbal instructions, but differentially under free and imagery instructions, with concrete words being better recalled.

Latency data

Latency of mediator production was recorded in milliseconds when the subject pushed a button indicating that he felt he had successfully applied the mediation instructions that he had been given. The data were analyzed via UCLA Biomedical Program BMD08V (Appendix D gives the condensed ANOVA table).

A simple main effect of instruction type was found, $F(2,54)=40.42$, $p<.001$. Neuman-Keuls analysis indicates that subjects seeking verbal mediators (M=8.56 sec.) responded more quickly than those who were not given a specific type of mediator to use (control condition, M=9.12 sec.), $p<.01$, and that the latter responded more quickly than subjects given instructions to use imagery mediators (M=9.96 sec.), $p<.01$.

A main effect of eye-movement type was found, $F(1,54)=95.61$, $p<.001$. Right-movers (M=8.59 sec.) responded more quickly than left-movers (M=9.84 sec.).

There was a main effect for word type, $F(1,54)=8.96$, $p<.01$, indicating that response was quicker for concrete words (M=9.04 sec.) than for abstract words (M=9.39 sec.).

A main effect for blocks, $F(3,162)=4.66$, $p<.005$, showed after post-hoc analysis (Scheffe, 1959) that subjects responded faster in block 3 (M=8.77 sec.) than in the other blocks (M=9.36 sec.), $p<.01$.

There was an interaction of instruction type and eye-movement type, $F(2,54)= 3.98$, $p<.05$. Figure #3 indicates that the differences between the mean latencies of mediator production under the three different instruction conditions were greater for left-movers than for right-movers.

There was an interaction of instruction type and word type, $F(2,54)=11.09$, $p<.001$. Figure #4 shows that the difference between response latencies for abstract as opposed to concrete words was greater under imagery instructions than under free instructions with longer latencies for abstract words; and that there were shorter latencies for abstract words under verbal instructions.

There was also a significant three-way interaction of instruction type, blocks, and trials $F(24,648)=1.52$, $p<.05$.

Post-study Interview

The group instructed to use imagery mediation reported doing so on most of the ten noun triplets included in the interview sample ($M= 7.1$ triplets). The verbal mediation group appeared to be somewhat better at complying with the instructions, reporting usage of a verbal mediator for nearly 90% of the triplets in the sample ($M= 8.8$ triplets). This is consistent with the greater availability of verbal mediators for abstract words (Yuille and Paivio, 1967). There was no significant difference within either of the above mediation groups as a function of eye-movement type.

The uninstructed control group reported using rote rehearsal for half of the interview sample (M= 5.6 triplets). Most of the remaining items for this group were evenly divided between verbal (M= 1.7 triplets) and imaginal (M= 2.1 triplets) mediators.

DISCUSSION

With respect to instruction conditions, the finding that long term recall was better facilitated by imagery mediation instructions (28% of the total words per block), than by verbal mediation instructions (25%), is a replication of prior results (Bower, 1972; Modigliani and Seamon, 1973). That the control (uninstructed) mediation condition resulted in poorest overall recall (22%) was unexpected, since the hypothesis that the two eye-movement groups would utilize their respective "typical" coding stragegies would lead to an expectation for the control condition mean of a value in the range of those for the verbal and imaginal mediation conditions. The post-study interview provided the most likely reason for this, indicating that approximately half of the subjects resorted to simple rehearsal as a coding strategy, and it has been shown (Modligiani and Seamon, 1974) that this is not a very effective method of verbal mediation.

The latency data were consistent with the recall data, with respect to instruction conditions. There were longer mediator acquisition latencies under imagery instructions (M= 10.0 sec.), than under verbal instructions (M= 8.6 sec.). This is a replication of a previous result (Paivio, 1966). The control condition fell midway between the other two conditions in mean latency (M= 9.4 sec.). Again, the post-study interview is relevant, as the subjects who were using rehearsal reported difficulty in deciding when to press the button to indicate they "had successfully applied the method " as they had been instructed to do. Some reported pushing the button immediately upon starting rehearsal, while others pushed it at various times during the mediation period when they felt that they had "learned" the words for that trial.

The findings with respect to word type were predictable from previous studies (Paivio, 1971). Concrete words were recalled better than abstract words (27% vs 23%) and mediators were found more quickly for the former (M=9.0 sec. vs M=9.4 sec.).

The significant interaction of instruction type and word type for both recall and latency dependent variables (see Figs. 2 and 4) constitutes another replication of previous work (Paivio, 1966; Yuille and Paivio, 1967). Under verbal instructions there was little difference in recall and latency between abstract and concrete words. With imagery instructions, concrete words showed better recall and shorter latencies than abstract words. The control condition also resulted in better recall of concrete than of abstract words, with shorter latencies for the former.

That right-movers had somewhat better overall recall than left-movers (26% vs 24%) was not unexpected as they were hypothesized to be more proficient at verbal processing in general. This was also reflected in the latency data where they had shorter average mediator acquistion latencies (M=8.4 sec.) than left-movers (M=9.9 sec.). The difference in time to acquire a mediator could underlie the superior recall of right movers as they would have more time remaining in the fixed length mediation period for encoding operations to take place.

Significant interactions of instruction condition and eye-movement groups occurred for both recall and latency data (Figs. #1 and #3), but were not in accordance with expectations based upon the hypotheses stated above. With respect to recall, it appears that there is little difference between right-movers and left-movers under the control (uninstructed) condition (22% vs 21%). Thus there is no evidence that the eye-movement groups tended to use "typical" methods of mediation when uninstructed. Right-movers showed the same amount of recall under verbal instructions as left-movers (25%). Most interesting and unexpected of all is the finding that right movers outperformed left-movers in recall under imagery instructions (31% vs 26%). The latency data were of little help in understanding this pattern of recall data. They show a greater spread among times to acquire mediators for left-movers than for right-movers, but the ordering of mean latencies for both groups was the same.

How is it that right-movers out performed left-movers under imagery instructions in a memory task? If you accept that they were in fact using imagery mediation, and the post-study interview and other data support this view, then it appears to be a question either of the differential time between the two groups to acquire mediators or some aspect of the imagery mediation process itself. The first prospect relates to the discussion above with regard to right-movers overall superior recall performance, with the additional possibility that added time for encoding operations to take place may be particularly useful in conjunction with imaginal mediators. The second alternative suggests that there could be some qualitative difference between the two groups in the utilization of imaginal mediators, perhaps right-movers have clearer, or better organized, etc. imaginal scenes to work with. At this point this is of course only speculation.

Rationale for Study II

Preparations were underway for a study to examine correlates of CLEMs with various measures related to visual imagery, when the unexpected results of Study I became known. At that point, The outcome of Study II became even more relevant, as information about the relative capablities of the eye-movement groups with respect to imagery ability might clarify the unexpected finding that right-movers outperformed left-movers in long term free recall under imagery mediation instructions. At the simplest level of analysis, if there was no indication of a relationship between eye-movement categories and performance on tests and rating scales theoretically sensitive to imagery ability, then the likelihood would be much greater that the differences seen in Study I were the result of differential performance on aspects of processing other than those resulting from the instruction to the subjects to form an interactive imaginal scene as a mediation device. The hypothesis that the superior performance of the right-movers was the result of their simply acquiring the mediatiors sooner would, among others, become more tenable and offer a more parsimonious explanation of the data.

There have been a number of studies done involving measures purporting to be sensitive to some aspect of imaginal ability. They are of basically two types, subjective ratings of various aspects of visual imagery, and objective tests that tap factors thought to involve the use of visual imagery for the solution of visuo-spatial problems.

The first type was represented in this study by the Sheehan (1967) revision of the Betts (1909) questionaire on vividness of imagery, and the Gordon (1949) test of visual imagery control (both printed with minor revisions in Richardson, 1969). It is this type of response measure that has previously been linked to CLEMs. Two studies have been done. Bakan (1969) reported that left-movers gave higher ratings on a subjective scale of vividness of visual imagery. Harnad (1972) studied faculty and graduate student members of a math department and found that the left-movers among them reported more frequent use of visual imagery in their work.

Subjective and objective imagery tests have been shown to be factorially independent (DiVesta et al, 1971) and it seems unclear what the former are measuring. Although Sheehan

(1966,1967,1972) has demonstrated their usefulness in the study of the differential performance of groups, selected on the basis of subjective imagery rating scales, in the area of memory for visual stimulus patterns of varying complexity.

Objective tests of imagery, the second category of measure used, have evolved through efforts to study psychological functions that are basically non-verbal in nature and that have been variously labelled as "perceptual", "visual ideation", "visuo-spatial" or "spatial". It is most likely that these gross categorizations subsume differentiable functions that together contribute to an individual's capacity for effective activity in the three-dimensional world.

The combination of factor analytic techniques with paper and pencil tests has enabled objective measurement of factors presumably related to spatial abilities. Subjective reports taken in conjunction with this type of research have often implicated the use of subjectively experienced visual imagery for the solution of spatial problems.

El Koussy (1935) identified a factor labelled "k" in a study using seventeen spatial tests of different kinds. His subjects reported the use of visual imagery in the solution of those tests that loaded heavily on "k".

Renshaw (1950) studied spatial abilities in the context of tests that required apparent rotation of two- and three-dimensional figures for the solution. The tests that loaded most highly on a factor described as "spatial" were those in which the subjects' said they had to visualize an object and then move it to an alternative position.

French (1951) identified a factor which was described as the ability to comprehend imaginary movement in three-dimensional space, or the ability to manipulate objects in imagination.

Costello (1956) noted that the ability to control visual imagery was more important than having vivid visual imagery for the solution of spatial tests.

Smith (1964, p. 98) felt that the essential aspect of the spatial factor is the ability to "form a mental image...to perceive and retain in mind a figure as an organized whole."

Shepard and his coworkers (Shepard and Chipman, 1970; Shepard and Metzler, 1971; Shepard and Feng, 1972) have developed tasks using two-dimensional and apparent three-dimensional figures in problems whose solution is thought to involve mental visual imagery.

Wilson, DeFries, McClearn, Vandenburg, Ashton, Johnson, Mi, and Rashad (1973) recently conducted a large scale study of cognitive structure. They identified four factors: verbal, spatial-visualization, perceptual speed and visual memory. The four tests with the highest loadings on the spatial-visualization factor were included in the study described here. They were: an adaptation of the Shepard-Metzler Block Rotation Test (requiring apparent three-dimensional rotation of block arrays); a two-dimensional Card Rotation Test; a Hidden Figures Test; and a paper and pencil Formboard Test.

Thurstone (1938) and DiVesta et al (1971) have shown that tests similar to these are factorially independent of those usually labelled as verbal tests, and that there is probably a genetic component in the ability to perform well on them (Thurstone, 1944). It therefore seemed useful to investigate the relationship between CLEMs and performance on materials that were less likely to be loaded in favor of left hemisphere abilities than those used in Study I.

Links between the right hemisphere and various kinds of visuo-spatal tests have been made in brain-damage research (Benton, 1969; Zangwill, 1953), in the area of neuropsychological testing (Reitan and Davison, 1974), and in the commissurotomy studies discussed above.

METHOD

Subjects

A total of 69 right-handed males completed all of the measures out of 84 in the original sample who did some portion of the tests. All were members of an introductory psychology class at Simon Fraser University, recruited as per Study I.

Materials

Four measures were selected to represent the spatial factor found by Wilson et al (1973) in their factor analytic study of cognitive measures. These were: the Shephard-Metzler Block Rotation task, consisting of twenty items, each of five two-dimensional pictures of a configuration of ten blocks connected together in an apparent three-dimensional space. The respondent is to identify which two of the remaining four pictures, shows a configuration of blocks which is the same as that in the first picture, except for a three-dimensional rotation.

The second measure was the Card Rotation Task. It presents rows of nine irregular shapes, with the goal of the task being to mark shapes in the row with a "+" or a "-" depending on whether the shape is a two-dimensional rotation of the first shape in the row (+), or a rotation of its mirror image (-).

The third test is a Hidden Patterns Test which required the identification of those figures containing a specified target pattern from among those in which the pattern is missing or incomplete.

The fourth measure was the Paper Formboard in which the subject is to mark lines on a complete geometric shape to show where it should be "cut" in order to produce an array of "pieces" like those shown alongside the complete figure.

Seven measures related to the vividness of sensory imagery were taken from the Sheehan revision of the Betts (1909) Questionaire on Mental Imagery (QMI). This task requires seven-point ratings of the subjective vividness of each of five images in each of seven sensory modalities (vision, audition, cutaneous, kinaesthetic, gustatory, olfactory, and organic).

Control of visual imagery was assessed by the Gordon (1949) Test of Visual Imagery Control (TVIC). This scale requires the subject to indicate whether he can, cannot or is unsure of attaining twelve specified visual imaginal scenes.

Measures of lateral eye-movement preference were taken as in Study I. Subjects were asked to reflect on and respond to twenty items selected after a prior study (Bakan, et al, 1972). The measure used was the proportion of right eye-movements among those questions that elicited lateral eye-movements.

Procedure

The Shephard-Metzler Block-rotation Task, Card Rotation Task, Hidden Patterns Test and Paper Formboard were group administered during a regularly scheduled class period. At the same session the revised Betts Q.M.I. and Gordon TVIC were distributed for the participants to do at home and return to the next class meeting.

Those who completed all of the above were contacted by telephone and an appointment was made for an interview to assess eye-movement preference. This was done as in Study I.

RESULTS

Characteristics of the Measures Used

Table I gives the means, standard deviations and estimated reliabilities of the measures used in this study.

Correlation and Factor Analysis

The correlation matrix (Pearson r) is presented in Table II. In general the absolute size of the correlations was moderate to low with 37 out of 78 in the table reaching .05 level of significance ($r > .23$, $N = 69$, two-tailed).

A principal-components analysis was performed on this correlation matrix. The unrotated factors are shown in Table III. The number of factors to rotate was chosen with reference to the rules-of-thumb given by Rummel(1970). Specifically, in order of priority, the scree test (Cattell, 1958), i.e. a flattening of the curve of variance accounted for by each successive factor; the eigenvalue greater-than-one rule (Kaiser, 1960); and a subjectively determined discontinuity in the eigenvalue curve (Cattell 1960). These considerations, taken in light of suggestions (Rummel, 1970) that it is better to rotate too many rather than too few factors, led to the rotation of the first four factors (accounting for 64.4% of the variance) to a varimax solution (Table IV).

The first rotated factor has high loadings from all of the Betts QMI scales except that for visual imagery. This factor would appear to represent vividness of imagery in non-visual modalities.

The second rotated factor has high loadings from the marker variables taken from the spatial factor of Wilson et al (1973). Although the relative sizes of the loadings of these variables orders them differently with respect to indexing this factor in this study compared to the Wilson et al study, this factor is assumed to be the same as that found in the latter study.

The third rotated factor is mainly loaded by the vividness of visual imagery scale of the Betts QMI, and will accordingly be labelled a visual imagery vividness factor.

The fourth rotated factor has as its only high loading the Gordon TVIC and will be labelled as a visual imagery control factor.

EMR, the index of degree of right eye-movements elicited, has its highest loading on the spatial factor. It has low loadings on the vividness of non-visual imagery factor and the vividness of visual imagery factor. It appears to be essentially unrelated to control of visual imagery as measured by the Gordon scale.

The Shephard-Metzler Block-Rotation Task, a relatively new test that has been purported to measure visual imagery, loads primarily on the spatial factor, with lesser loadings on vividness of imagery factors.

The vividness of visual imagery scale of the Betts QMI is relatively unique among this set of variables and is not strongly associated with any of them, although there is a minor negative loading on the visual imagery control factor that is consistent with previous reports (Richardson, 1969). Sheehan (1967) has demonstrated the usefulness of this test in the context of memory for visually presented patterns, so it might be more likely related to a factor like that found in Wilson et al (1973) that was labelled visual memory.

The Gordon TVIC is likewise unique among the set of measures used in this study. Except for the above mentioned negative correlation with vividness of visual imagery, it appears to be unrelated to any of the other measures.

In order to see what the relationship of CLEMs might be to the first three factors and to determine in what way right-movers might differ from left-movers with respect to these factors, a manual plot of the subjects' factor scores was done on two-way combinations of these factors. It was immediately apparent that while there was considerable overlap between the groups, there was a clear differentiation between them along the dimension defined by factor 2 and none on factors 1 and 3. Right-movers tended to score higher on factor 2, which is defined by the block rotation task, the card rotation task, the hidden figures task and the formboard.

In order to determine the relative efficacy of the various imagery tests as predictors of eye-movement direction, a multiple regression analysis (Nie, Hull, Jenkins, Steinbrenner, and Bent, 1975) was done. The results of the analysis that included all of the imagery measures is shown in Table V. The multiple correlation coefficient of .71 indicates that these measures account for 51% of the variability in eye-movement direction. The increment in the multiple correlation coefficient resulting from the addition of each independent variable to all of the others, is shown in column 1 of Table V. The first three measures accounted for significant ($p < .05$) amounts of variance with the Shepard-Metzler Block-Rotation Task accounting for 27.5%, the Card Rotation Task 8.7%, and the Hidden Patterns Test 3.3%. The signs of the standardized regression weights indicate that the first two of these independent variables are positively related to a predominance of right eye-movements, while the Hidden Patterns Test shows a negative relationship.

DISCUSSION

The studies reported here were done to assess the relationship between CLEMs and variables that are in theory functionally related to the right hemisphere, although Study I involved left hemisphere functions in part. These variables were the type of mediation instruction, and kind of noun (abstact or concrete) to be remembered in Study I. In Study II they were objective tests of visuo-spatial ability and subjective ratings of imagery vividness and controlability.

Because the prior available findings relating CLEMs to imagery (Bakan, 1969; Harnad, 1972) utilized subjective rating methods, leaving it unclear whether the reported differences between right- and left-movers represented variation in proclivity or capability, the present studies each provided the opportunity to make this distinction. In the first study an uninstructed group was included to provide comparison with the two groups who received specific instructions to utilize verbal or imaginal mediators. The second study included objective tests as well as subjective rating scales.

The results of these studies did not support hypotheses relating individual differences in the predominant direction of CLEM's to performance on tasks assumed to be utilizing functions localized in the right hemisphere. These studies did however, indicate consistent relationships between predominant direction of CLEM and performance on materials involving visuo-spatial and imaginal abilities.

Study I failed to show any difference in recall between groups under the control mediation condition. There was also no data from the post-study interview indicating that the groups tended to use different mediation strategies. Thus there was no evidence of the two groups displaying a spontaneous preference for using a coding strategy hypothetically related to one or the other hemisphere. There was also no difference in recall between the groups under verbal mediation instructions, although left-movers took longer to acquire verbal mediators. This would seem to suggest that once a verbal mediator is found, the effectiveness of this technique has been achieved. The lack of the expected superiority of right-movers with verbal mediation, could be due to population characteristics, as university students have quite likely been screened for verbal abilities prior to appearing as subjects.

The most unexpected finding from Study I was the superiority of right-movers' recall under imagery instructions. This implied that either right-movers had relatively greater capability to use this form of mediation, or that there was an interaction such that early acquisition (right-movers had shorter latencies) of an imaginal mediator resulted in better long term free recall.

In Study II, a predominance of right eye-movements (just the opposite of what was expected under simple hypotheses that the principle direction of CLEM indicated involvement of the contralateral hemisphere, and that the other tests tapped a right hemisphere function) was found to be significantly related to performance on three of four objective visuo-spatial tests, and weakly related to four of seven subjective non-visual imagery rating scales. CLEMs were not found to be related to subjectively rated vividness and control of visual imagery, failing to support to the findings of Bakan (1969) and Harnad (1972).

The results of Study II, taken in conjunction with those of Study I, appear to indicate that right-movers have a greater capability, but not necessarily a preference, for visuo-spatial imaginal information processing.

The equivocal nature of the results with respect to simple hypotheses about the relationship of CLEMs and hemispheric specialization can perhaps be best resolved within the framework of Dimond (1972), whose viewpoint might be termed hemispheric integration. While acknowledging that various functions may be more or less localized to one or the other of the cerebral hemispheres, his position emphasizes the interactive nature of their functioning in situations involving complex information processing.

From this standpoint it is possible to conjecture that the kinds of tasks used here are not as dependent on solely right hemisphere functions as is often assumed, and that perhaps right-movers are better "integrated" in the sense of being able to coordinate functions resident in both hemispheres for more efficient combined performance.

The visuo-spatial, imaginal tasks used here all involved directed imagery, as opposed to undirected daydream-type imagery as studied by Singer (Singer and Antrobus, 1963). The "directed" aspect may be related to sequential processing which has been associated with left hemisphere activity (Bogen, 1969a, 1969b). Such a component might be less prominent in unstructured daydreaming.

Right hemisphere functions may be necessary but not sufficient for superior performance on tasks like those used here. Such a view is consistent with studies tending to relate deficits in visuo-spatial performance to right-hemisphere or bilateral brain damage, but less so to left hemisphere damage alone (Strauss and Kephart, 1955; Wedell, 1959; Costa and Vaughan, 1960).

That right-movers could turn out to be better integrated, such that both right and left hemispheres are well developed functionally and both are utilized in conjunction or in rapid succession during problem solving is a matter for further consideration. Such an interpretation could account for the greater speed with which right movers acquired mediators in the memory study, as well as their superior performance on the objective visuo-spatial tasks. Such an hypothesis would require further testing of the two groups under conditions that would allow such capability to be clearly demonstrated.

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Figure #1: Percentage of Long Term Recall as a Function of Eye-movement Type and Instruction Type (Study I).

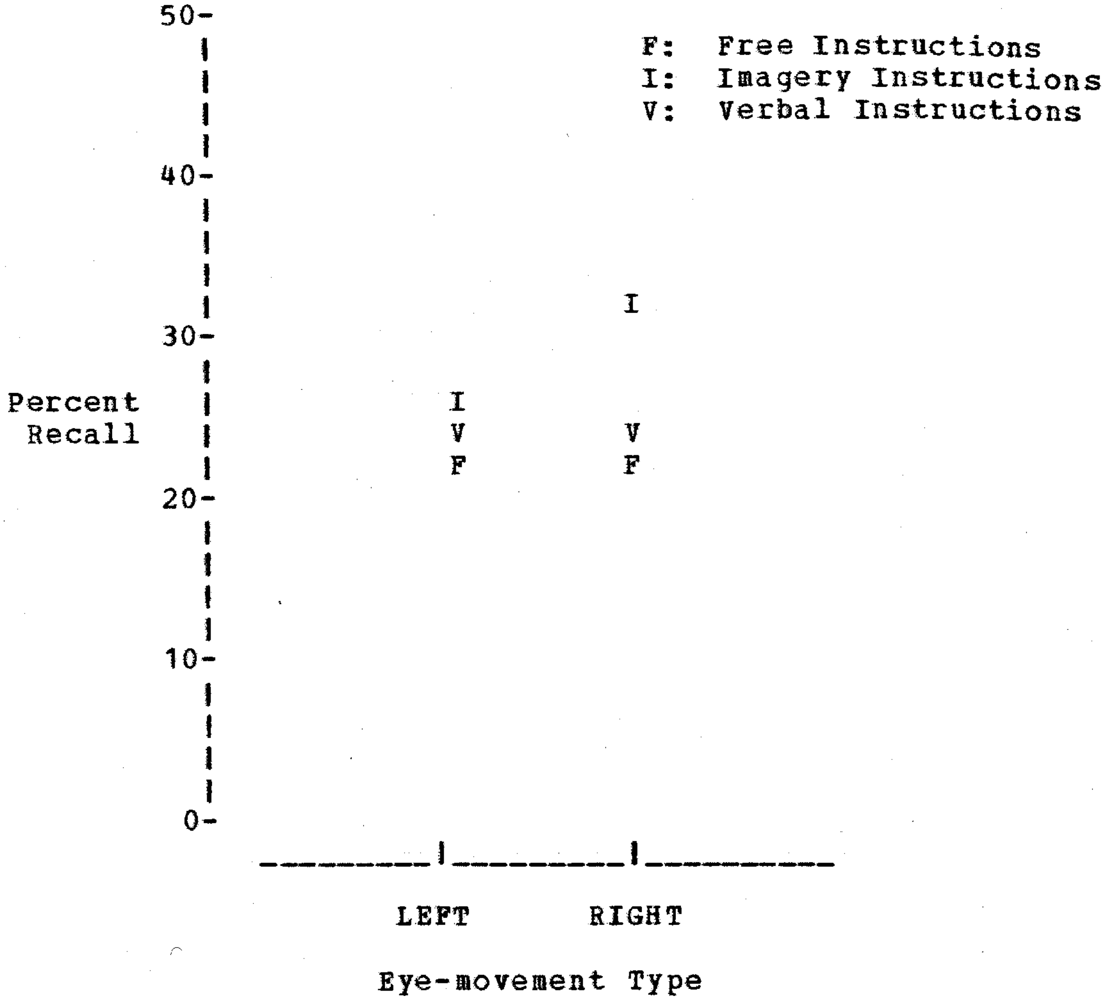

Figure #2: Percentage of Long Term Recall as a Function of Instruction Type and Word Type (Study I).

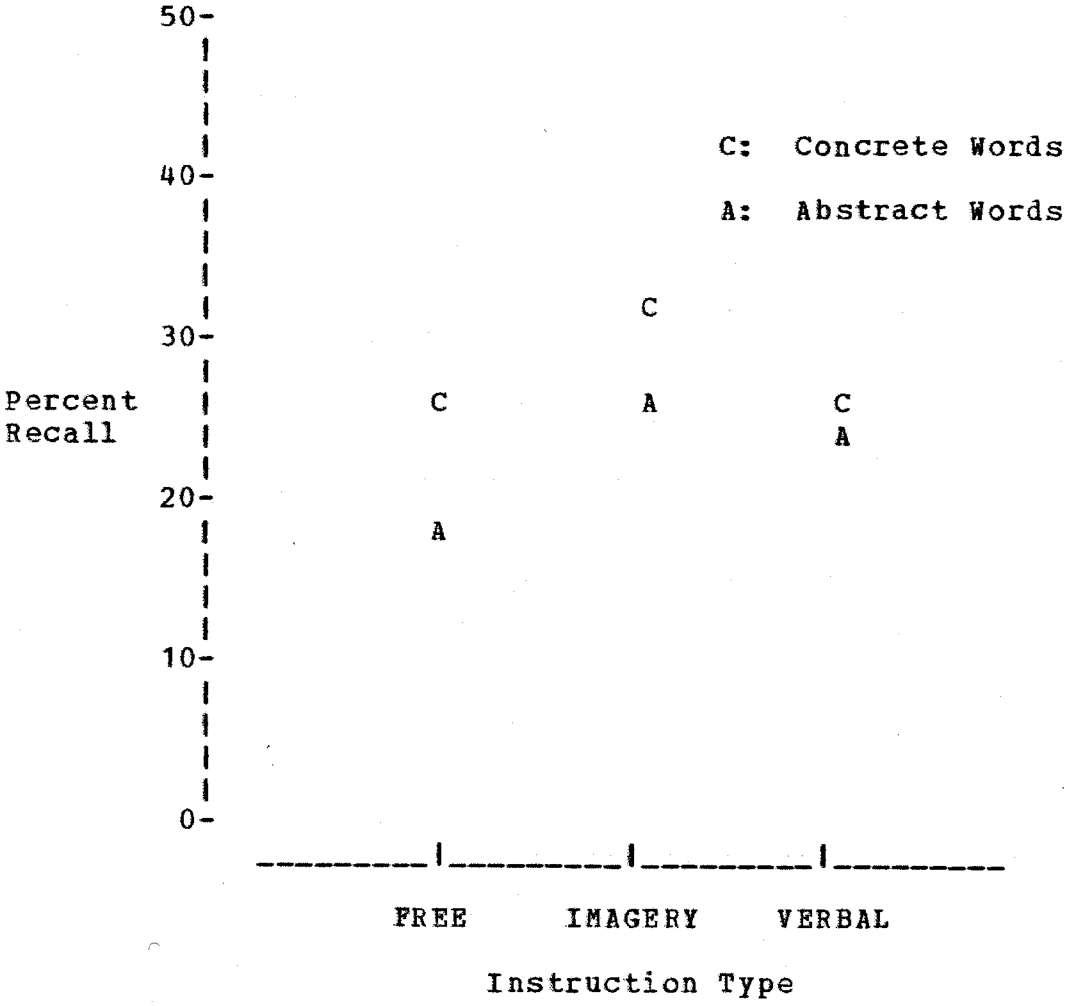

Figure #3: Response Latency as a Function of Eye-movement Group and Instruction Type (Study I).

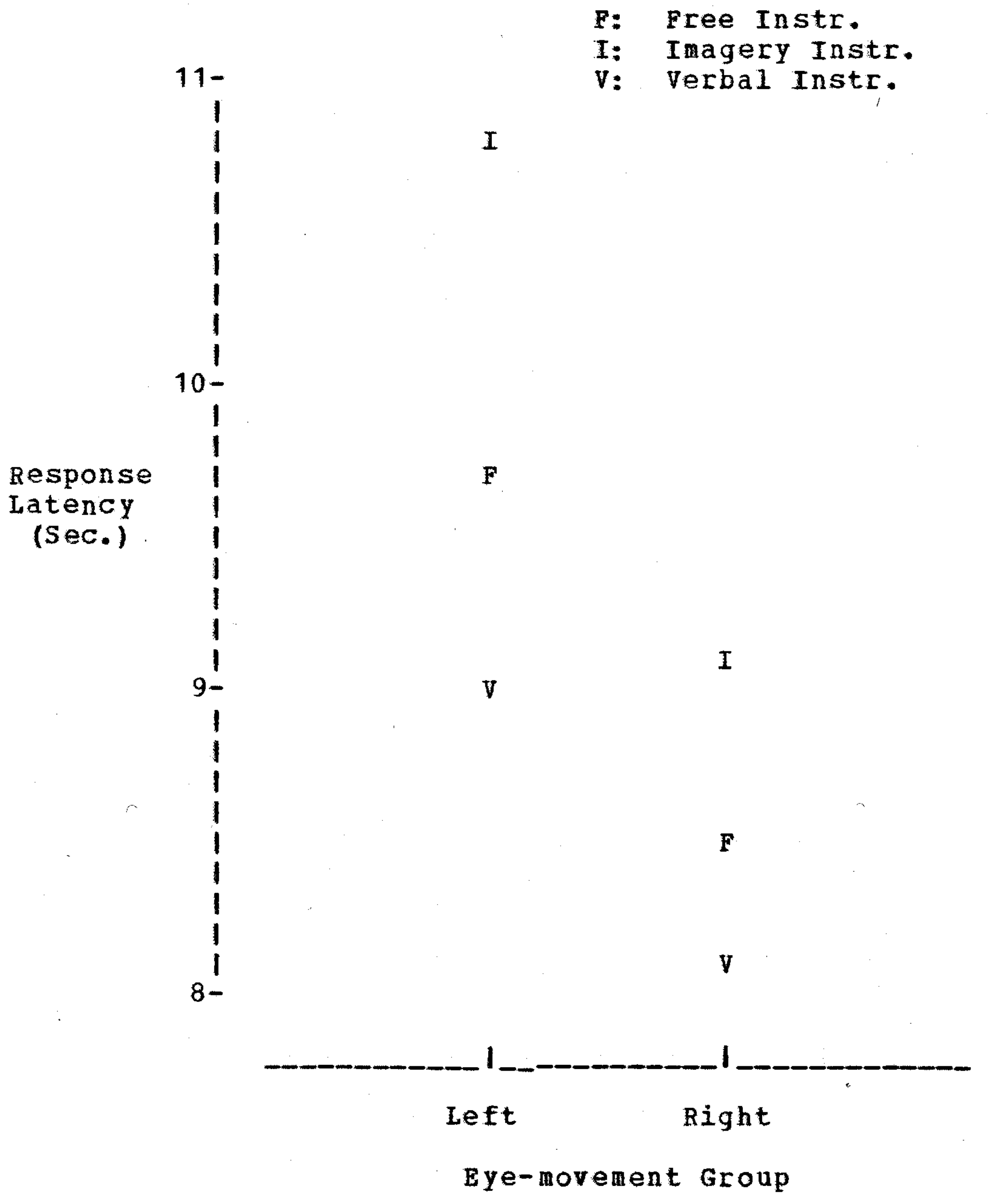

Figure #4: Response Latency as a Function of Instruction Type and Word Type (Study I).

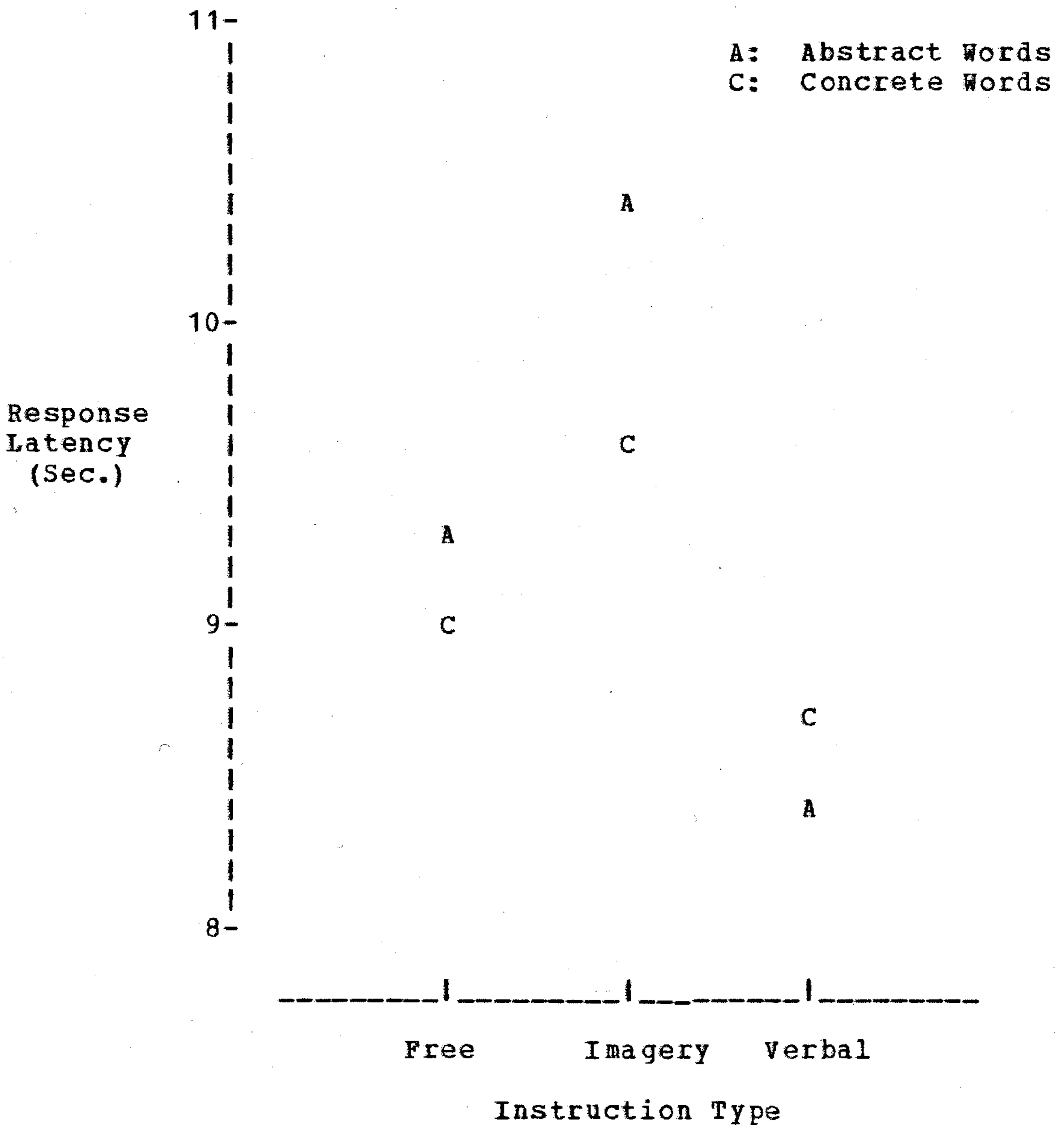

Table I: Characteristics of Measures Used in Study II

Variable Name	Mean	S.D.	Reliability
Shep. Block Rotation	21.46	6.62	.88 (a)
Card Rotation	89.36	25.67	.88 (b)
Hidden Patterns	67.25	21.78	.92 (b)
Formboard	10.74	3.31	.84 (a)
Betts Q.M.I. Total	85.73	21.16	.78 (c)
Visual	12.12	3.93	--
Auditory	13.17	4.63	--
Cutaneous	12.13	3.76	--
Kinaesthetic	12.33	3.75	--
Gustatory	12.65	4.70	--
Olfactory	14.39	5.12	--
Organic	11.45	3.68	--
Gordon T.V.I.C.	19.45	4.09	.72 (c)
CLEM (Prop. of eye-movements to right)	0.51	0.33	.72 (d)

(a) KR-20 (Wilson et al, 1973)
(b) CR alpha (Wilson et al, 1973)
(c) Test-retest (Richardson, 1969)
(d) Test-retest (Bakan and Strayer, 1973)

Table II: Pearson Product-Moment Correlation Matrix (Study II)
(r >.23, p <.05, n=69)

	SHEP	CARDT	HIDT	FORM
CARDT	0.43389			
HIDT	0.35672	0.45326		
FORM	0.35580	0.53099	0.27114	
VIST	0.21048	0.14061	-0.14981	-0.01230
AUDT	0.21318	-0.05545	-0.03441	0.15746
CUTT	0.25206	0.05646	0.05867	0.10908
KINT	0.23224	0.08527	0.05171	0.09116
GUST	0.25790	0.17625	0.07072	0.15040
OLFT	0.30301	0.08929	0.06111	0.16055
ORGT	0.15217	-0.01579	-0.06626	0.16234
CONT	-0.11155	-0.07733	0.00931	-0.20304
EMR	0.49395	0.46722	0.20730	0.32940

	VIST	AUDT	CUTT	KINT
AUDT	0.19239			
CUTT	0.28287	0.62443		
KINT	0.27695	0.58913	0.57421	
GUST	0.30929	0.45817	0.62122	0.43101
OLFT	0.33972	0.41954	0.38605	0.28478
ORGT	0.10120	0.43567	0.46466	0.44762
CONT	-0.18770	-0.26360	-0.18650	-0.35686
EMR	0.14667	0.11913	0.32141	0.15032

	GUST	OLFT	ORGT	CONT
OLFT	0.39025			
ORGT	0.34934	0.39700		
CONT	0.11284	-0.21152	-0.13717	
EMR	0.25302	0.23977	0.27903	-0.12342

Table III : Unrotated Principal Components (Study II)

	FACTOR 1	FACTOR 2	FACTOR 3	FACTOR 4
SHEP	0.56510	0.48643	-0.10921	0.13704
CARDT	0.36692	0.76144	-0.12988	-0.01704
HIDT	0.20384	0.63566	0.32222	0.02940
FORM	0.40921	0.55756	0.12211	-0.33169
VIST	0.42812	-0.16543	-0.78432	0.15366
AUDT	0.69406	-0.39052	0.23018	-0.11600
CUTT	0.76964	-0.28461	0.16829	0.16844
KINT	0.69592	-0.30235	0.11734	-0.21956
GUST	0.69706	-0.15627	0.02532	0.29650
OLFT	0.62756	-0.12558	-0.18349	0.11719
ORGT	0.59823	-0.27577	0.31545	0.04552
CONT	-0.38534	0.08327	0.25018	0.79992
EMR	0.54053	0.45166	-0.06707	0.17986
Eigen Values:	4.08	2.21	1.06	1.02
% Var:	31.40	17.00	8.10	7.80

Table IV : Varimax Rotated Factors (Study II)

	FACTOR 1	FACTOR 2	FACTOR 3	FACTOR 4
SHEP	0.21735	0.69329	0.24190	0.01563
CARDT	-0.09039	0.83762	0.12311	-0.08149
HIDT	0.00483	0.67040	-0.30568	0.08605
FORM	0.09051	0.67216	-0.15125	-0.34697
VIST	0.14953	0.02798	0.90157	-0.11595
AUDT	0.80611	-0.02192	0.01946	-0.22360
CUTT	0.83040	0.11709	0.16178	0.02438
KINT	0.71512	0.04802	0.08232	-0.34237
GUST	0.67700	0.19751	0.28745	0.13747
OLFT	0.50975	0.17659	0.40262	-0.06217
ORGT	0.72761	0.04595	-0.05744	-0.02603
CONT	-0.16462	-0.05861	-0.13475	0.89955
EMR	0.23330	0.65471	0.21263	0.06875
Sum of Sq.:	3.25	2.60	1.34	1.15
% Var.:	25.10	20.10	10.40	8.80

Table V : Multiple Regression of Imagery Measures on Proportion of Right Eye Movements (Study II)

	CHANGE IN MULTIPLE R	BETA
SHEP	.275	.315
CARDT	.087	.397
HIDT	.033	-.209
FORM	.002	.056
VIST	.002	-.069
AUDT	.008	-.115
CUTT	.026	.287
KINT	.006	-.103
GUST	--	.003
OLFT	.001	.029
ORGT	.058	.216
CONT	.010	-.142

Appendix A

1. What is the meaning of the proverb: A watched pot never boils?

2. What is the meaning of the proverb: It is an ill wind that blows no one good fortune?

3. Make up a sentence using two forms of the same verb.

4. Tell me two verbs beginning with "N".

5. What is the meaning of the proverb: A poor worker blames his tools?

6. Spell "therapeutic".

7. What is the meaning of the proverb: Call no man happy 'till he's dead?

8. List two adverbs.

9. What is the meaning of the proverb: Lend your money and lose your friends?

10. What is the meaning of the proverb: More than enough is too much?

11. List two propositions.

12. What is the meaning of the proverb: Words should be weighed not counted?

13. What is the meaning of the proverb: He is rich who has few wants?

14. Define inflation.

15. What is the meaning of the proverb: A rolling stone gathers no moss?

16. Make up a sentence using two adverbs.

17. Tell me two verbs beginning with "R".

18. What is the meaning of the proverb: The hardest work is to go idle.

19. What is the meaning of the proverb: What saddens a wise man, gladdens a fool?

20. Define the word economics.

Appendix B: Instructions to Subjects (Study I)

Instructions: "The first thing you will see is this red light labelled 'warning' which will come on for two seconds. Following that, three words will be projected across this screen here (indicating), directly above the lights. They will stay on for three seconds, plenty of time to read them aloud, which is what I want you to do. When the three words are projected, I expect you to read them out loud. Then nothing will happen for fifteen seconds. During that time I want you to do your best to remember those three words."

The verbal instruction group was then told: "I want you to use a particular method to remember those words. This method has been shown to be a highly effective way in which to memorize sets of words. It's very simple. Take the words and connect them with other words or phrases to make a composite if you can. For example, if the words are chief, animal and metal, you might compose the phrase 'the chief animal is metal'.

The imagery instruction group was told: "I want you to use a particular method to remember those words. It has been shown that when people use this method to memorize sets of words, they can do so in a highly effective way. It's very simple. Take the words and connect them together in an imaginary scene so that they are all touching one another. For example, if the words are chief, animal and metal, you might picture an indian sitting on an animal holding something made of metal, perhaps a shield."

The free instruction group was told: "You are free to use any method you wish to remember those words. It has been shown that when people are free to choose any method they wish to memorize sets of words, they can do so in a highly effective way. Use whatever method feels most suitable to you to remember the words."

Then for all groups: "When you have successfully applied the method , press this button and continue to apply the method until the end of the period. I will ask you later to tell me in detail how you applied the method to specific sets of the words you will see. If you can't use the method for a particular set of words, say 'I can't do it' and don't press the button. There is no hurry to press the button. It simply allows me to tell when you feel you have successfully applied the method."

"After the period of time in which you are to try to remember the words, this green light labelled 'trial words' will come on for three seconds. At that time I want you to recall aloud the three words you were attempting to memorize on that trial. Let's go over it again. A trial begins when this red warning light goes on, then three words are projected on this screen and you will read them out loud. After that you try to memorize them using the method we talked about. Then you recall out loud those three words when the green light comes on."

If the subject indicated he understood at this point E continued: "The sequence we just went over describes one trial. As soon as a trial is over, the red light will come on again for the next trial . There will be ten trials in a row, each just as I have described. After the tenth trial, this white light labelled 'read' will come on. At that point I want you to begin reading this material out loud until the white light goes out. As the white light goes out this amber light labelled 'recall all words' will come on. When that happens I want you to recall as many of the words as you can remember from all of the words that you have seen projected during the entire study up until that time. You will have five minutes to recall aloud any words you can remember from those that were projected. If you're not sure whether you've already recalled a word, say it again. Do you understand what you are to do so far?"

If the subject indicated that he did, E continued: "What I have just described constitutes one block. At the end of the period in which you are to recall aloud all the words you can remember, the amber light will go out and the red warning light will come on again to signal the start of another block of ten trials. There will be five blocks of ten trials in all. At the end of each subsequent block there will be a period for you to recall all the words you can remember from those that were projected up to that time. This includes words from previous blocks. Try to recall aloud all the words you have seen projected. Do you understand?"

If the subject indicated that he did, E continued: "Now we will go through some warm-up trials together until you have the procedure down, and then you will have the first block as practice on your own to get used to it." At this point E stepped through the trial procedure coaching the subject until he had responded correctly on his own for two consecutive trials. Then E left the booth and started the equipment for the first block. If the subject follwoed instructions throughout the first block the equipment continued to run for four subsequent blocks.

Appendix C: Analysis of Variance Table: Long Term Memory Recall as a Function of Instructions, Eye-movement Type, Blocks, and Word Type. (Study I)

Source	df=	Error Term	MSS=	F=	P<
INSTRUCTIONS (N)	2	S(NM)	42.86456	29.7327	.001
E-M GROUP (M)	1	S(NM)	10.80000	7.4913	.01
BLOCKS (B)	3	SB(NM)	1.472221	1.0761	N.S.
WORD TYPE (W)	1	SW(NM)	45.63333	40.0051	.001
NM	2	S(NM)	7.168703	4.9725	.01
NB	6	SB(NM)	.5701354	0.4167	N.S.
MB	3	SB(NM)	2.283333	1.6689	N.S.
NW	2	SW(NM)	9.777016	8.5711	.001
MW	1	SW(NM)	.1333313	0.1169	N.S.
BW	3	SBW(NM)	1.449997	1.1788	N.S.
S(NM)	54		1.441662		
NMB	6	SB(NM)	.9854177	0.7203	N.S.
NMW	2	SW(NM)	2.914574	2.5551	N.S.
NBW	6	SBW(NM)	.6437657	0.5234	N.S.
MBW	3	SBW(NM)	.4388905	0.3568	N.S.
SB(NM)	162		1.368132		
SW(NM)	54		1.140688		
NMBW	6	SBW(NM)	.9034109	0.7345	N.S.
SBW(NM)	162		1.230021		

Appendix D: Analysis of Variance Table: Response Latency as A Function of Instructions, Eye-movement Group, Blocks, Trials and Word Type. (Study I)

Source	df=	Error Term	MSS=	F=	p<
Instructions (N)	2	S(NM)	399.3870	40.4226	.001
Eye-movement Group (M)	1	S(NM)	944.6816	95.6128	.001
Blocks (B)	3	SB(NM)	52.31833	4.6547	.005
Trials (T)	4	ST(NM)	12.37534	1.5401	ns
Word Type (W)	1	SW(NM)	76.09442	8.9580	.01
NM	2	S(NM)	39.35840	3.9835	.05
NB	6	SB(NM)	13.55564	1.2060	ns
MB	3	SB(NM)	11.47667	1.0211	ns
NT	8	ST(NM)	8.499617	1.0578	ns
MT	4	ST(NM)	7.173122	0.8927	ns
BT	12	SBT(NM)	6.153662	0.6506	ns
NW	2	SW(NM)	94.20035	11.0895	.001
MW	1	SW(NM)	5.449768	0.6416	ns
BW	3	SBW(NM)	9.873911	1.1808	ns
TW	4	STW(NM)	7.272678	0.7212	ns
S(NM)	54		9.880280		
NMB	6	SB(NM)	2.245996	0.1998	ns
NMT	8	ST(NM)	7.719408	0.9607	ns
NBT	24	SBT(NM)	14.33559	1.5157	.05
MBT	12	SBT(NM)	7.702653	0.8144	ns
NMW	2	SW(NM)	9.616150	1.1320	ns
NBW	6	SBW(NM)	3.058542	0.3658	ns
MBW	3	SBW(NM)	7.431183	0.8887	ns
NTW	8	STW(NM)	5.801245	0.5753	ns
MTW	4	STW(NM)	7.168362	0.7109	ns
BTW	12	SBTW(NM	11.45894	1.3811	ns
SB(NM)	162		11.23980		
ST(NM)	216		8.035219		
SW(NM)	54		8.494588		
NMBT	24	SBT(NM)	8.150270	0.8617	ns
NMBW	6	SBW(NM)	5.977849	0.7149	ns
NMTW	8	STW(NM)	9.296806	0.9220	ns
NBTW	24	SBTW(NM	11.58261	1.3960	ns
MBTW	12	SBTW(NM	2.950101	0.3556	ns
SBT(NM)	648		9.458200		
SBW(NM)	162		8.361750		
STW(NM)	216		10.08347		
NMBTW	24	SBTW(NM	6.031765	0.7270	ns
SBTW(NM)	648		8.297170		