DOCUMENT RESUME

ED 109 639 CS 002 041

AUTHOR Rigney, Joseph W.; Lutz, Kathy A.
TITLE The Effects of Interactive Graphic Analogies on Recall of Concepts in Chemistry. Technical Report No. 75.
INSTITUTION University of Southern California, Los Angeles. Dept. of Psychology.
SPONS AGENCY Office of Naval Research, Washington, D.C. Personnel and Training Research Programs Office.
REPORT NO TR-75
PUB DATE May 75
NOTE 64p.

EDRS PRICE MF-$0.76 HC-$3.32 PLUS POSTAGE
DESCRIPTORS *Cerebral Dominance; Chemistry Instruction; *Computer Assisted Instruction; Computer Graphics; Concept Teaching; Eye Movements; Higher Education; *Learning Processes; Memory; *Nonverbal Learning; Reading Processes; Reading Research; *Recall (Psychological); Verbal Learning; Visual Aids

ABSTRACT

Forty undergraduate college students participated in a computer-assisted instructional study designed to utilize right cerebral hemisphere functions in the learning and memory process. Two versions of a lesson on how a simple battery works were designed to present conceptual and topographic information either verbally or pictorially on a Plato IV terminal. The unique feature of this terminal for studying imagery is that it can produce animated interactive graphics. The effects of the type of information presentation on learning and attitudinal outcomes were investigated. The lesson that incorporated animated graphics resulted in higher scores on recall tests of knowledge, comprehension, and application. Students found this lesson to be more attractive. Subjects in the treatment providing external imagery reported experiencing more internal imagery than did the group receiving the verbal version. (Recent research about the different information processing functions of the right and left cerebral hemispheres as they relate to imagery in learning and memory is reviewed.) (Author/MKM)

DEPARTMENT OF PSYCHOLOGY

UNIVERSITY OF SOUTHERN CALIFORNIA

Technical Report No. 75

THE EFFECTS OF INTERACTIVE GRAPHIC ANALOGIES ON RECALL OF CONCEPTS IN CHEMISTRY

May 1975

Joseph W. Rigney
Kathy A. Lutz

Sponsored by

Personnel and Training Research Programs
Psychological Sciences Division
Office of Naval Research

and

Advanced Research Projects Agency
Under Contract No. N00014-75-C-0838

ARPA TECHNICAL REPORT

30 May 1975

1.	ARPA Order Number	: 2284
2.	ONR NR Number	: 154-355
3.	Program Code Number	: 1 B 729
4.	Name of Contractor	: University of Southern California
5.	Effective Date of Contract	: 75 January 1
6.	Contract Expiration Date	: 75 December 31
7.	Amount of Contract	: $200,000.00
8.	Contract Number	: N00014-75-C-0838
9.	Principal Investigator	: J. W. Rigney (213) 746-2127
10.	Scientific Officer	: Marshall Farr
11.	Short Title	: Learning Strategies

This Research Was Supported

by

The Advanced Research Projects Agency

and by

The Office of Naval Research

And Was Monitored by

The Office of Naval Research

SUMMARY

Recent advances in knowledge about the different information processing functions of the right and the left cerebral hemispheres, and laboratory studies of these different functions were reviewed for their implications for training and education. The evidence is that the right hemisphere is specialized for spatial and topographic imagery processes, while the left is specialized for serial, analytical, language processes. The two hemispheres have different degrees of access to the vocalizing system on the midline, which is primarily under the control of the left hemisphere, and to the motor systems for the right and left hands. Under certain conditions, the left hemisphere can override control over these systems by the right. The task that is given to the subject, the orienting task, not only determines the subsequent information processing done to mediate responding, but also influences where this processing is done in the cerebral hemispheres. Recent studies of the effects of mental imagery on learning and memory predominantly find strong positive effects. In verbal learning whatever mental imagery adds, a spatial organization, an integrating context, or a second coding, it is clear that it results in better retention and recall in the laboratory.

The implications of this for training and education are that the right hemisphere functions have been relatively neglected in the predominantly verbal mediation of instruction and knowledge. The challenge to instructional technology is to utilize the dual-coding system more effectively.

The first of several planned studies, using interactive, animated graphics for illustrating the abstractions, concepts and laws of science, and for stimulating imaginal processes in students, is described in this report. It was found that these graphics did have positive effects on the learning of concepts in electro-chemistry, as measured by recall tests of knowledge, comprehension, and application, and that the lesson containing these graphics was more attractive to students than a lesson in which purely verbal explanation was used. Subjects who took the lesson providing external imagery reported experiencing more internal imagery than did the subjects who received the verbal version.

These positive outcomes encourage further research into (1) better methods for inducing mental imagery in students than verbal instructions, (2) theoretical foundations for the processing of external imagery relating it to current theories of the structure of long term memory, and (3) objective indicators of mental imaging that would be more reliable than verbal reports of subjects.

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER Technical Report 75	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) THE EFFECTS OF INTERACTIVE GRAPHIC ANALOGIES ON RECALL OF CONCEPTS I CHEMISTRY		5. TYPE OF REPORT & PERIOD COVERED Semi-annual Technical Report 1 January - 30 June, 1975
		6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) Joseph W. Rigney, Kathy A. Lutz		8. CONTRACT OR GRANT NUMBER(s) N00014-75-C-0838
9. PERFORMING ORGANIZATION NAME AND ADDRESS Behavioral Technology Laboratories University of Southern California Los Angeles, California 90007		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS NR 154-355 N 62887 1B 729
11. CONTROLLING OFFICE NAME AND ADDRESS Personnel and Training Research Programs Office of Naval Research (Code 458) Arlington, VA 22217		12. REPORT DATE May 1975
		13. NUMBER OF PAGES 55
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)		15. SECURITY CLASS. (of this report)
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

CAI
IMAGERY

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Two versions of a CAI lesson on how a simple battery works were designed to elaborate conceptual and topographic information either verbally or pictorially. The effects of the type of information presentation on learning and attitudinal outcomes was investigated. The lesson that incorporated animated graphics resulted in higher scores on recall tests of knowledge, comprehension, and application. Students found this lesson to be more attractive. Subjects in the treatment providing external imagery

DD FORM 1473 1 JAN 73 EDITION OF 1 NOV 65 IS OBSOLETE
S/N 0102-014-6601

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

#20

reported experiencing more internal imagery than did the group receiving the verbal version.

The possibility of an interaction between eye-movements during tests of verbal and pictorial processing and attitudes toward the two CAI lessons was suggested by the data. These outcomes are generally supported by the literature on mental imagery in learning and memory.

ACKNOWLEDGEMENTS

The research discussed in this report was monitored by Dr. Marshall Farr and Dr. Joseph Young, Personnel and Training Research Programs, Office of Naval Research, and by Dr. Harry F. O'Neil, Jr., Program Manager, Human Resources Research, Advanced Research Projects Agency. Their support and encouragement is gratefully acknowledged.

The authors also wish to thank Professors Richard J. Lutz and Masao Nakanishi of the University of California at Los Angeles for their helpful comments and assistance with the data analysis.

ABSTRACT

Two versions of a CAI lesson on how a simple battery works were designed to elaborate conceptual and topographic information either verbally or pictorally. The effects of the type of information presentation on learning and attitudinal outcomes was investigated. The lesson that incorporated animated graphics resulted in higher scores on recall tests of knowledge, comprehension, and application. Students found this lesson to be more attractive. Subjects in the treatment providing external imagery reported experiencing more internal imagery than did the group receiving the verbal version.

The possibility of an interaction between eye-movements during tests of verbal and pictorial processing and attitudes toward the two CAI lessons was suggested by the data. These outcomes are generally supported by the literature on mental imagery in learning and memory.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

I. INTRODUCTION

CAI terminals, such as the PLATO IV plasma panel, provide capabilities for a certain amount of animation, and for accepting pointing responses (touch panel) from the student. Together, these capabilities constitute a unique medium for interacting with the student and an attractive technology to use for research on the effects of certain types of imagery on learning and memory. Review of the literature bearing on mental imagery and the general outlines of an experiment to investigate the effects of animated, interactive graphics on learning about invisible processes were set forth in an earlier report.

In this report, more recent research relating to imagery in learning and memory is reviewed, and the design and results of the study, outlined earlier, are described.

II. RECENT RESEARCH ON FUNCTIONS OF THE CEREBRAL HEMISPHERES

A number of lines of research are resulting in better knowledge about right and left cerebral hemisphere functions, inter-hemispheric communications, the interrelations between the hemispheres and the motor systems, and the effects of orienting tasks on hemispheric processing. This information is of relevance to studies of the effects of both external and internal imagery in learning and memory. Therefore, some selected recent articles from these areas of research are reviewed in this section.

Techniques for Studying the Functions of the Cerebral Hemispheres

Information on lateralization of brain function has come from a variety of sources ranging from studies using autopsy of the brain to recent studies of split-brain and callosal disconnection syndrome cases, using orienting tasks. A chronological classification of much of the research on brain laterality by McNeil and Hamre (1974) includes these categories:

Autopsy studies. Patients who suffered loss of speech were found to have "softening" or other types of damage and disorders within the left hemisphere of the brain.

Handedness correlates. A three-way correspondence between handedness, cerebral dominance, and language has been assumed but recent evidence suggests that although right-handers usually have a language dominant left-hemisphere only 1/3 of left-handers are right-hemisphere dominant.

Cortico-anatomical techniques. The following are examples of these techniques used with patients:

1) Hemispherectomy. Removal of the left hemisphere causes loss of speech while removal of the right hemisphere r little or no language impairment.

2) Cortical mapping. Electrical stimulation to the left hemisphere interferes with language tasks.

3) Studies of split brains. When the two hemispheres of the cerebrum are disconnected, the right hemisphere is seen to be specialized for "appositional" processing, while the left-hemisphere is seen to be specialized for "propositional" processing.

Intracarotid sodium technique. When sodium amytal is injected into the patient's left or right carotid artery, functions of one hemisphere are degraded temporarily, thereby allowing analyses of some hemisphere functions. Injections affecting the left hemisphere usually interfere most with speech and language functions.

Dichotic techniques. When auditory stimuli are presented simultaneously to each ear (which transmit the stimuli primarily to the contralateral hemisphere), the dominant hemisphere for processing can be identified. Results indicate that language is processed in the left hemisphere while nonverbal stimuli are processed in the right.

Dichoptic techniques. Different visual stimuli are simultaneously presented to each visual field so that each hemisphere perceives only one of the stimuli. This technique has been used with "split-brain" patients. Results of recent studies are discussed in this section.

Split-Brain Research

Nebes (1974) reviewed recent studies of hemispheric specialization in commissurotomized man. In normal brains, the corpus callosum and other commissures and pathways at cerebral and brain-stem levels provide for inter-hemispheric communication. It could be argued, therefore, that evidence from split-brain research does not apply to normal brains. But, it seems unlikely that the functions of the hemispheres would be totally different when partially disconnected from other areas by severance of commissural pathways. Of course, several hypotheses are possible. Left and right hemispheres might be identical halves of a fully-duplexed information-processor. One half might serve in a standby mode while the other half did all processing. Neuroanatomy and traumas to right or left halves indicate this hypothesis is wrong. Or, each hemisphere might have unique functions, coordinated at brainstem levels. The existence of the corpus callosum and other cerebral commissures suggest that this could be only partly true. Finally each hemisphere might have both unique and common or shared functions. Current neuroanatomical and clinical evidence favors this hypothesis.

On the question of shared functions, section of the interhemispheric tracts eliminates much of the normal integration of sensory information between the two sides of the brain. On the unique function question, cortical areas concerned with speech functions have been well-localized in the left hemisphere of right-handed individuals, with even anatomical differences being observed between these regions in the right and left hemispheres (Geschwind, 1972).

The information from split-brain studies contributes some tantalizing glimpses of cognitive phenomena to the background for research in training and education. The following information is taken from Nebes' (1974) review of split-brain research.

Language. The left hemisphere is proficient in all language skills, confirming the evidence from other sources. The right hemisphere can recognize words and can cause words to be copied. It usually cannot produce names associated with objects; and it cannot express itself in speech through the speech mechanisms. It appears to have great difficulty comprehending verbs. Gazzaniga and Hillyard (1971) concluded that the right hemisphere cannot recognize the relationships between subject, object and verb.

In the number identifying tasks that Gazzaniga and Hillyard (1971) gave the right hemisphere there was the possibility that the dominant (left) hemisphere could have shared in the processing by "silently reciting the list of possible choices," and by being cued to verbalize the correct choice when the right hemisphere perceived it. (See Krashen, 1975 for further details).

Minor-hemisphere functions. These were classified by Nebes under spatial relations, part-whole relations, and non-verbal stimuli. In the series of studies whose results are summarized below, the right hemisphere, left (or right) hand combination was superior to the left hemisphere, right hand combination.

1. Spatial relationships:

    1.1 Free choice situation: Line orientation, direction of movement; Right hemisphere predominates.

1.2 Choose two-dimensional layout that would reproduce three dimensional shape S held in right or left hand: right hemisphere, left hand superiority.

1.3 Select the tactile design which would complete a visual pattern (Raven's coloured progressive matrices): right hemisphere, left hand far superior--was more concerned with spatially related moves.

1.4 Copy Greek crosses or two-dimensional representations of three-dimensional cubes: patients performed better with left hands (at a time when they could write only with their right hands), specific right-hand apraxia.

1.5 Manipulation of KOHS blocks: left hand would spontaneously reach out to correct (apraxic) right hand.

2. Part-whole relations: (Right hemisphere is superior in generating concept of complete stimulus configuration from partial or fragmentary data.)

2.1 Choose one of three circles from which arc was taken. Examine either arc or circle or both with right or left hand.

2.1.1 Feel arc, visually select circle.

2.1.2 Feel both arcs.
Left hand best (right hand at chance level).
Right hemisphere, left hand far superior on these tasks.

2.2 Match felt forms to form of fragmented visual figure, if reunited; right hemisphere, left hand far superior.

3. Non-verbal stimuli: (No verbal label or too complex to specify in words.) (RH damage results in difficulty in recognizing and remembering faces, nonsense figures, or complex patterns).

3.1 Visual Chimeras. (These are symmetrical pictures, such as a human face, made up from two halves of slightly different images, e.g., faces. Each half is presented to a different hemisphere by tachistopic methods, so that the right hemisphere sees one half-image and the left hemisphere sees the other half-image. When orienting tasks appropriate for right hemisphere processing are given the subject, the half-image presented to the right hemisphere is seen as a complete, symmetrical picture. Orienting tasks appropriate for left hemisphere processing result in the half-image it sees being completed).

3.1.1 Point with right or left hand to correct picture in array of pictures; S completes right hemisphere image.

3.1.2 Name or verbally describe the stimulus; S completes left hemisphere image.

3.1.3 Point to picture of object whose name rhymed with name of object they had seen. Left hemisphere controlled this, right side of chimera was completed. (Note that when commissurotomy patients had to associate names with faces, verbal naming faculties were cut off (LH) from facial recognition faculties (RH).

3.1.4 Line drawings for chimerical stimuli. S must pick from array one which is similar to item he had seen; visually similar object resulted in right hemisphere match. Conceptually similar object resulted in left hemisphere match.

In these studies, the minor hemisphere controlled the motor output not only of the left hand but also of the right. In the competition for the motor channels, it is the hemiphere which is most competent for the function involved which assumes control over the motor system.

The significance of these studies of right hemisphere functions for research on imagery in training and education is that they clearly indicate the right hemisphere does have unique functions, which seem to be analog rather than propositional in nature. The right hemisphere makes important contributions to the spatial representation and memory of the external world, and may be the principal basis for imitative learning. This possibility is suggested more strongly in Geschwind's work on the apraxias, reviewed below.

The studies using chimerical images add interesting evidence of the effects of orienting tasks on hemispheric processing. When the orienting tasks required verbalization, the half-picture projected to the left hemisphere was perceived by the subject as a complete (symmetrical) picture.

When the orieting task required only pointing, it was the half-picture presented to the right hemisphere that was seen as whole, regardless of which hand was used to make the pointing response. What part of the nervous system "fills in" the missing half of the picture in these cases is not clear, although it is presumably the hemisphere to which the half picture is projected. Perhaps, it is too great an inferential leap to speculate that requiring normal subjects to make pointing responses on a PLATO IV terminal touch panel, instead of typing responses on the keyboard, results in more right than left hemisphere processing of graphic images displayed on the plasma panel.

The Apraxias

Geschwind (1975) has reviewed recent research on these disorders, which he defines as "disorders of the execution of learned movement which cannot be accounted for either by weakness, incoordination, or sensory loss, or by incomprehension or inattention to commands" (p. 188). The studies reviewed investigated the effects of the human callosal disconnection syndrome, which results from different locations and amounts of the corpus callosum being damaged.

Study of the apraxias in humans with this syndrome shed light on interhemisphere communication through different parts of the corpus callosum, and on the origins of these pathways in each hemisphere; and also on localization of memory for motor skills. The evidence for interhemispheric communication described by Geschwind is important because it supports the hypothesis that each hemisphere has some unique functions which must be available to the other hemisphere when certain types of orienting tasks are assigned. For this reasons, Geschwind's description of some interhemispheric pathways involved in apraxias is given below (p. 188).

> The patient, who was observed over many months, would carry out commands with his right arm, correctly and without hesitation--for example, 'Show me how you would use a hammer,' 'Wave goodby.' However, when given commands for his left arm, such as 'Show me how you would use a comb with your left hand.' he would usually either make no response or would make a clearly incorrect response. He could use his left arm quite normally for these tasks under other circumstances: if the examiner performed the act, the patient could imitate with his left arm, or if the patient were handed a hammer or a comb, he handled them normally.
>
> The fully correct performance by the left arm ruled out the possibility that the failure to respond to verbal commands could be the result of weakness, incoordination, or any other elementary disorder involving the left arm. The correct response of the right arm to verbal commands ruled out inattention, incomprehension, or uncooperativeness on the part of the patient. How could we then account for these paradoxical results? We concluded, on the basis of both these findings and other observations given in more detail in our original paper, that the patient had suffered destruction of the anterior four-fifths of his corpus callosum, a finding confirmed at postmorten examination.
>
> In order to clarify the mechanisms of disorders such as this one, let us consider the anatomical pathways by which movements are carried out to verbal commands. A vast amount of evidence has accumulated over the past 100 years demonstrating that in the overwhelming majority of adult humans the capacities for production and comprehension of language are mediated by certain regions in the left hemisphere. In particular, a region known as Wernicke's area is usually involved in the comprehension of spoken language. When the subject receives an order to carry out a movement with the <u>right</u> hand, this order is probably transmitted from Wernicke's area through the lower parietal lobe to the left premotor region. The premotor region, in turn, probably controls the precentral motor cortex, which gives rise to the pyramidal tract--a major pathway for motor control--which sends fibers to the spinal cord, where it activates the nerve cells controlling the muscles.
>
> When a command is given to the subject to carry out an action with the <u>left</u> hand, the order must also pass through

> Wernicke's area in the left hemisphere. Two alternative routes might be taken from this point. One goes from Wernicke's area to the left premotor region, from there via the corpus callosum to the premotor region of the right hemisphere, and from there to the right precentral motor cortex, which controls the left limbs. The alternative route goes from Wernicke's area to the corresponding region in the right hemisphere and from there to the right premotor and precentral motor regions. This alternative route is probably not the one predominantly used, since damage to this pathway--when the more anterior route is spared--does not lead to apraxia in the left arm, with perhaps occasional very rare exceptions.
>
> As a result of the destruction of the anterior four-fifths of the corpus callosum in our patient, the verbal command could not reach the right hemisphere and thus failed to initiate correct responses by the left limbs. On the other hand, when the examiner demonstrated the actual motor performance, language comprehension was no longer necessary because the patient's right hemisphere could <u>observe</u> and <u>imitate</u> correctly. When an object, for example, a hammer, was placed in the left hand, the right hemisphere could also respond to the visual stimulus with the correct movement.

When considered in the context of the above discussion of pathways, the evidence from these studies bearing on localization of memory for motor skills fits another small piece in the puzzle of how orienting tasks influence hemispheric processing. It may be, too, that this kind of information ultimately will have some implications for the ways in which hands-on training is done. The following excerpts from Geschwind's article convey the essence of the findings (p. 191).

> This notion that the left hemisphere may be the major respository for motor learning also accounts for the fact--again pointed out by Liepmann and readily observable in the clinic--that the left limbs of patients with right hemiplegia are often unusually clumsy. What makes the disability of these patients even more remarkable is the fact that normals who lose the use of the right arm because of peripheral causes--for example, having the arm in a cast as the result of a fracture--rapidly become very dexterous in the use of the left limbs. By contrast, the patient with a right hemiplegia often shows even poorer performance with his left limbs than an unpracticed normal would exhibit. The reason is that the patient with a fracture of the right arm can learn to use his previous store of motor skills in the left hemisphere to direct the control of the

left-arm by the right hemisphere. The patient with a right hemiplegia who has suffered destruction of the left premotor area, has lost a significant part of his motor learning.

This theory permits us to detect a significant flaw in the common teaching that motor learning takes place throughout the brain. People who have learned to write with the right hand can, without practice, write with the left hand, or a foot, or even with a brush in the mouth. It is therefore argued that the whole brain must have learned the skills. This theory, however, suggests that the ability of an untrained part of the body to carry out a task may indicate that another region in which actual learning has taken place is directing the naive area.

One need not assume that in all cases only the left hemisphere learns motor skills. In some instances its learning may be superior to that of the right hemisphere or even simply more accessible. For example, even when the apraxic patient fails to imitate the examiner correctly, he usually does improve when shown an actual object or permitted to handle it. While the patient may not correctly 'blow out' an imaginary match and may still perform incorrectly after seeing the examiner carry out the pretended task, he may respond without error to the sight of a real, lighted match. This suggests that the right hemisphere may have a store of motor learning that is released only when given much more information. However, we find that some apraxic patients, although a minority, fail to respond properly not only the verbal command and imitation but also to the sight or handling of an object. It is often difficult to prove that such a patient does not have a more elementary motor disorder."

Hemisphere Specialization in Normals

Studies of the lateralization of brain function in normal subjects have also indicated that each hemisphere is specialized in terms of function. One study found that verbal stimuli elicit left hemisphere processing in normal subjects while pictorial stimuli elicit right hemisphere processing. This study by Calloway and Harris (1974) examined the shift in EEG while subjects processed different types of external stimuli (printed text, pictures, or music) and found that there was a shift to the right side when the stimuli were pictures or music, and a shift to the left side when the subject was reading printed text. In addition, the effect of type of processing inducement on brain function was investigated by having the subject compose a letter "mentally" with eyes closed. This task also resulted in an EEG shift to the right indicating increased right hemisphere processing.

Similar findings come from the work of Kimura (1973) in that the right hemisphere was dominant during music and visual tasks (except reading) while the left hemisphere dominated for auditory tasks involving speech. Using a dichotic listening task, Kimura found that most subjects reported words heard with the right ear (which transmits primarily to the left hemisphere) more accurately than those heard with the left ear. But the opposite was found for the dichotic perception of music; the melody played in the left ear (to the right hemisphere) was better recognized than the one played in the right ear. In addition to the dichotic listening technique, Kimura used a dichoptic technique to assess the visual perception ability of each hemisphere. Letters and printed words seem to be processed primarily in the left hemisphere while depth perception, two-dimensional point locations, and dot enumeration tasks were predominantly handled by the right hemisphere.

Another measure of cerebral specialization in normal subjects is direction of certain lateral eye movements while thinking. The assumption is that cognitive activity which is primarily centered in one hemisphere will cause eye movements contralateral to that hemisphere. Support for this assumption includes studies which show that electrical stimulation to one hemisphere of the brain causes eye movements away from that stimulated side (Penfield and Roberts, 1959). A recent study by Kinsbourne (1972) claims to offer support for the assumption that "the direction in which people look while thinking reflects the lateralization of the underlying cerebral activity." In the first of two experiments, subjects' eye and head movements were recorded in response to verbal, spatial, and numerical problems. For right-handers, eye movements were usually to the right for verbal questions, and were generally to the left during spatial problems. In left-handers, movements were not predominantly to one side or the other, a finding consistent with evidence that left-handers are not as well lateralized as right-handers (Hacaen and Ajuriaguerra, 1964). The second experiment yielded similar results with right-handers looking to the right during verbal processing and to the left during spatial processing.

A number of other studies have yielded very different results than the Kinsbourne study--they found that the direction of eye movement is fairly consistent for a given individual so that a subject may be classified as a "left-mover" or "right-mover"(Bakan, 1969; Bakan, 1971; Weitan and Etaugh, 1973). The assumption is that a person has a dominant or preferred hemisphere that more easily and regularly processes information regardless of the type of question or processing inducement. Comparisons between right-movers and left-movers have revealed several cognitive and personality correlates of lateral eye movements. Right-movers (assumed to be left-hemisphere dominant) do better on concept identification tasks than left-movers but worse on spatial and imagery tasks.

There seems to be conflicting evidence that 1) eye movements reflect the type of task and underlying brain processing and 2) eye movements reflect the individual's dominant hemisphere. A recent study shed light on this conflict by finding that lateral eye movements are influenced by the position of the experimenter (Gur et al., 1975). When the questioner, faces the subject, his eye movements tend to reflect his dominant hemisphere. But when the questioner sits behind him (and a hidden camera records his eye movements), the eye movements will respond to the type of question and reflect the underlying cognitive activity. The explanation is that subjects' eye movements indicates their dominant hemisphere when in a stressful or anxiety arousing situation.

Other studies of cerebral specialization in normals remind us that brain processing is not task specific--that is, certain tasks or types of stimuli do not automatically elicit certain types of brain processing. Such a conclusion would be an oversimplification. In the processing of music, for example, studies cited earlier found that music may be processed in the right hemisphere. But a more appropriately designed study has revealed that music can be processed differently by different people. Bever and Chiarello (1974) found that musicians recognize simple melodies better in the right ear (which is linked with the left hemisphere) than in the left, while the reverse is true for non-musician listeners. The musicians were also able to analyze the selection for component tone sequences better when it was presented to the right ear. Musicians apparently analyze music while the non-professional listener does not. The researchers concluded from these results that the left hemisphere is dominant for processing of an analytical nature while the right hemisphere is dominant for holistic processing.

III. RECENT STUDIES OF HEMISPHERIC SPECIALIZATION IN LEARNING AND MEMORY

The large number of articles on the topic of imagery now appearing in the journals dealing with learning and memory attest to its current popularity as a research topic.

A very small sample of these articles ~~is reviewed~~ below, to illustrate paradigms and hypotheses, and to give the flavor of some current research on right and left hemisphere processing in normal subjects. These studies are loosely categorized according to certain techniques and hypotheses now current in this research. All of these are concerned in one way or another with elucidating the functions of the right and left hemispheres, although each technique may focus on a different aspect of these functions.

Paivio's Dual-Coding Hypothesis

According to Paivio (1974), the dual-coding approach has several general assumptions: 1) verbal and nonverbal information are represented and processed in distinct but interconnected symbolic systems; 2) the nature of the symbolic information differs qualitatively in the two systems such that one system deals with synchronous or spatial information (pictures) while the other deals with sequential information (language); and 3) both systems are dynamic rather than static information stores so that information can be reorganized, manipulated, or transformed. The dual-coding hypothesis posits that both imagery and verbal codes are stored for pictures and for concrete words.

One testable implication of the dual-coding hypothesis is that visual memory images should be more effective for remembering spatial relationships, and that verbal codes should be more effective for remembering temporal relationships. Snodgrass and Antone (1974) tested this implication and found, for pictures and word pairs presented either in a spatial or in a temporal relationship, that spatial memory was superior to temporal memory, and picture memory was superior to word memory, but that there was no interaction between type of relationships and type of material. They interpreted this as not supporting the dual-coding hypothesis, because no evidence was obtained that verbal codes are specialized for sequential processing and pictorial codes for parallel processing.

Selective Interference Between Coding Systems

Several studies have provided evidence for independent coding systems. One line of evidence shows that a perceptual task and a memory task interfere with each other if the two involve the same store or system. A selective interference technique is used in which spatial and verbal orienting and interfering tasks are presented simultaneously in like or different processing-mode combinations.

Using this technique Salthouse (1974) attempted to determine whether nonverbal visual stimuli were represented in memory in a verbal or spatial format. In the two experiments, the Ss were required to remember either the positions or the identities of seven target items in a 25-item array under selective interference conditions. He concluded that the two experiments provided an unequivocal answer to the question; a spatial or visual representation is clearly implicated. The primary support for the notion of separate memories was found in the selective interference when different types of recall information are remembered concurrently with different types of recognition information. In both experiments, the most interference resulted when the same type of information is involved in the two simultaneous tasks. The interference is either greatly reduced or eliminated when different types of information are involved in the two tasks.

In a more recent study, Salthouse (1975) investigated the generality of the selective interference phenomenon by studying several different concurrent tasks, each involving either verbal or spatial information, and a range of retention intervals from 10 to 30 sec. Interference in performance was greater when the two simultaneous tasks were both verbal or both spatial.

Byrne (1974) used a version of the selective interference technique that calls to mind the series of experiments with split-brain humans, reported by Nebes (1974) and summarized above. Byrne was interested in the effects of two types of responses, visually-guided pointing, at a column of Y's and N's on a card, or saying "yes" or "no." The general task for the subjects was to memorize a list of words and then, from memory, to successively categorize each item for the presence or absence of a certain characteristic (e.g., does the word refer to an animal). The assumption was that, if the word list requires visual imagery, then the visually-guided pointing response should disrupt recall.

In a series of five experiments, he varied the conditions of acquisition in a way that would or would not produce conflict between memory functions and perceptual activity during recall. Conflict in this case suggests that S is storing (or attempting to store) the material in imaginal form. He found consistent results across a variety of stimulus material: (1) a visually guided response does seem to disrupt recall of a list of items learned under conditions regarded as likely to induce mediating imagery, and (2) this visual conflict is most evident when the items are spatially organized, and seems largely independent of item concreteness. This suggests that the presence or absence of spatial organization is an important characteristic of stimulus material when it comes to predicting whether the material will be coded imaginally. Byrne demonstrated that this spatial quality may be present in the word's references (e.g., house) or physically present in the stimulus material (spatially ordered pictures). Byrne's results using the selective interference technique support Paivio's assumption that the two stores are functionally distinct.

Another kind of supporting evidence for Paivio's dual-coding hypothesis comes from studies comparing reaction times for coding concrete words and pictures in either store. In a series of three experiments, Paivio and Begg (1974) investigated the speed of visual search when pictures and their verbal labels served both as target stimuli and as arrays through which the search was conducted. Reaction time for visual search through the arrays was the principal dependent variable. They interpreted their results as most consistent with a dual-coding hypothesis. Items that are cognitively represented both verbally and as nonverbal images can be searched and compared in either mode.

In another series of experiments Paivio and Csapo (1973) found that verbal and visual stimuli are independent in the sense that they have "additive" effects on recall--that is, repeating a word as a picture or a picture as a word practically doubles recall whereas repeating a picture twice or a word twice in succession does not enhance recall so greatly.

Imagery and Imagery Instructions

Dewing and Hetherington (1974) investigated the effects of high imagery value words on times required to solve anagrams. They proposed that, if noun imagery facilitates the availability of the words as units, it would follow that anagrams of High-I words would be easier to solve than those of Low-I words. They found the imagery effect to be highly significant and to be clearly independent of word frequency and associative meaningfulness.

Lesgold et al. (1974) have conducted a number of studies on the effects of giving imagery instructions to several age groups on recall of prose material and have found that instructing the S to picture in his mind what is going on in the passages to be read, or to use the information to draw or construct a picture from cutouts enhances recall significantly.

Groninger (1974) studied the effects of instructions to image given at the time of acquisition vs at the time of recall, on a test of recognition memory for 50 high imagery-value and 50 low imagery-value words. He found that imagery instructions at presentation (acquisition) resulted in superior performance on the recognition memory test.

Forbes and Reese (1974) were interested in the effects of progressive imaginal elaboration versus single-item elaboration in a multilist paired associates paradigm, using free and serial recall, and controlling for repetition of old list responses in progressive elaboration. Although they expected progressive elaboration to result in superior free recall it and single-response elaboration produced equal facilitation when response repetition was controlled. They also found that response repetition in the context of elaboration provides more facilitation than is provided by single-response elaboration.

Tversky and Sherman (1975) presented evidence indicating that both recognition and recall of pictures improve as picture presentation time increases and as time between pictures increases. According to results of their study, processing of the pictures, rehearsal and or encoding, continues after the picture has disappeared, just as for verbal material. This contradicts the assumption that "there can be no analog of verbal rehearsal in the visual memory system that can be applied to moderately complex visual stimuli." (Atkinson & Shiffrin, 1968).

This finding is not surprising for recall, where verbal encoding strategies can be used during "off-times." The improvement in recognition performance due to increased off-time is surprising. Moreover, the virtual absence of a correlation between correct recognition and recall in this study indicated that subjects were retrieving different information to pass each type of test.

Madigan (1974) presented subjects with a number of lists that contained six different kinds of events: Items presented twice in either picture (pp) or word (ww) form; items presented once in each form, in one order or the other (pw, wp), and items presented as words (w) or as pictures (p) once only. In a following immediate free recall test, subjects were required to recall names of items, and also to identify all recalled items by specifying one of the six kinds of events specified above.

The results strongly indicated that subjects easily remembered the symbol modality of presentation of recalled items. That is, they had very little difficulty in remembering if the verbal labels they recalled corresponded to items originally presented in a verbal or pictorial form. Further, more items that had been presented pictorially were recalled than items that had been presented verbally.

Madigan and Rouse (1974), investigated the effects of increasing exposure on recall of names and recognition of orientation of complex pictures. Both recall and recognition became more accurate with increasing exposure duration during learning, holding inter-item interval constant. The accuracy of these performances was largely unrelated within each exposure duration.

In a second experiment, they found that different types of cues strongly influenced recognition of picture reversal. When the (uninformative) cue, "next," preceded the test picture, recognition latencies were longer than when the name of the picture was the preceding cue, for both "same" and "different" discriminations.

The results of these two experiments suggest that "verbal and pictorial features of complex visual stimuli are retained independently (in memory) and that pictorial information, represented as such in memory, can be readily generated" (p. 151).

Peterson (1975) investigated the retention of imagined and seen spatial matrices. The nature of imagery and its relationship to perception were probed by having students recall the contents of 4 x 4 spatial matrices after they constructed the matrices through the processes of mental imagery, seeing, or verbal coding.

In the first experiment, students were instructed to construct mental images of the matrices and their contents while listening to auditory messages over earphones that directed them to mentally place letters into the imaginary matrix. In the second experiment, the matrices actually were seen by the students, each for 5 seconds. In the third experiment, students listened to the auditory messages used in the first experiment, but were not instructed to construct mental images.

Recall (using the partial report technique with probes) was best when students saw the matrices, intermediate in the imagery situation, and poorest in the verbal situation.

The recall of imagined matrices was similar to that of seen matrices. The contents of the corner cells in the matrices were recalled more often than the contents of other cells in the matrix. This implies that the internal representations induced by both imagined and seen matrices are spatial in nature, and that processes involved in the imaginary construction of a spatial matrix from auditory messages provided information similar to that obtained from actually viewing the matrices.

In contrast to these results of experiment I and II, the results from experiment III contained the strong primacy and recency effects of serial verbal learning, and the proportion of items correctly recalled was much lower than in experiment I or II.

Comparison between results of experiment I and III (both groups heard the same tapes, but only I was instructed to image while listening) indicate that the subjects could in some way control the processing of information. The imagery instructions to Group I permitted some conscious control which influenced the processing of matrices.

Peterson speculated that processing of this sort may be multi-stage in the nervous system, and that it is monitored by a "coding evaluator" that operates at a very early stage of processing.

The Effects of Context on Memorability and Recall

Jenkins (1974) contends that memory is a constructive process in which "what is remembered in a given situation depends on the physical and psychological context in which the even was experienced, the knowledge and skills that the subject brings to the context, the situation in which we ask for evidence for remembering, and the relation of what the subject remembers to what the experimenter demands" (p. 793).

In the non-trivial learning tasks characteristic of education and training, both analog and digital processing in Attneave's (1974) terms, are usually required. Language is an indispensable tool in learning. Where the interest is in teaching about the abstract concepts and invisible processes in science, graphical images may be constructed to represent these invisible entities. But if not supplemented by language, these external images would be ambiguous or meaningless. This requirement for a deep structure context for graphic images is beautifully illustrated in the study by Bower, Karlin, and Dueck (1975). The following figure is from that study.

This figure is not only relatively meaningless as is, but is also unmemorable as was demonstrated. But, when it is asserted that this is a drawing of a midget playing a trombone in a telephone booth, the figure is suddenly endowed with both meaning and memorability.

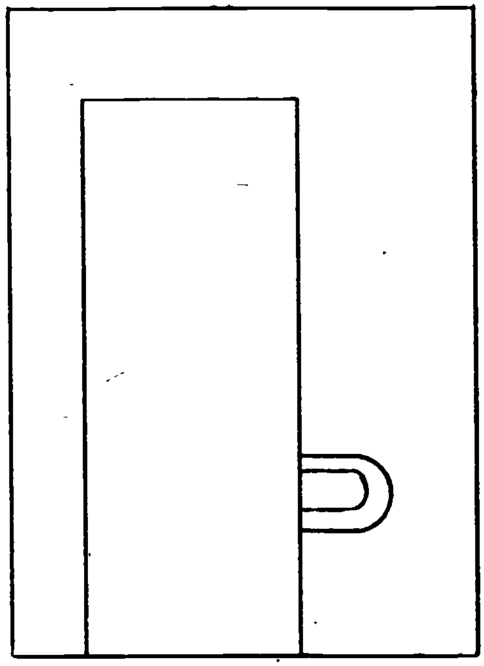

Figure 1. The Surface Structure of a Graphic Image. (Bower, et al., 1975, p. 217)

Bower, Karlin, and Dueck reported two experiments investigating the thesis that people remember nonsensical pictures much better if the pictures are given in a meaningful context. In the first study, they found that free recall (S had to draw all the pictures he could remember in 10 minutes) of "droodles" was much better when the subjects received verbal interpretations of them during study. In the second experiment, they found that subjects who were given a linking interpretation during study of pairs of nonsensical pictures showed greater associative recall and matching. The authors concluded that memory is aided whenever contextual cues arouse appropriate schemata into which the material to be learned can be fitted. In similar vein, the following figure has low meaning and memorability when presented without labels.

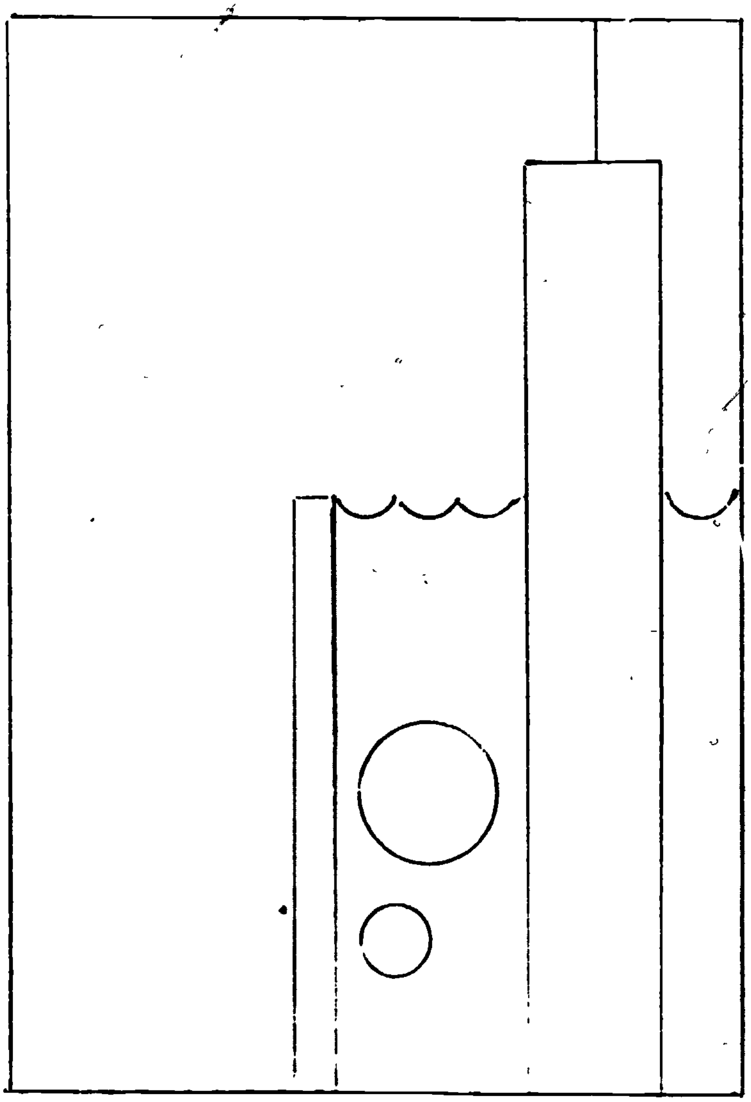

Figure 2. The Surface Structure of Another Graphic Image.

When the large circle is labelled "NH_4+" the small circle "Cl^-" and the long, thin rectangle "cathode", the wavy lines are then seen to represent the surface of an electrolyte, the long rectangle an electrode, and the scene takes on some meaning as part of some kind of simple electrochemical apparatus. When this image is shown in the context of a lesson about how a simple battery works, it takes on additional meaning. Finally, when the image is shown on a plasma panel and the two circles are made to move appropriately, the movement becomes meaningful when related to a physical law.

An illustration of the importance of context for the meaning of verbal passages is taken from Bransford and Johnson (1973). (See also Norman, et al., 1974). Reading through the passage yields very little information about what it is describing:

> The procedure is actually quite simple. First you arrange things into different groups. Of course, one pile may be sufficient depending on how much there is to do. If you have to go somewhere else due to lack of facilities that is the next step, otherwise you are pretty well set. It is important not to overdo things. That is, it is better to do too few things at once than too many. In the short run this may not seem important but complications can easily arise. A mistake can be expensive as well. At first the whole procedure will seem complicated. Soon, however, it will become just another facet of life. It is difficult to foresee any end to the necessity for this task in the immediate future, but then one never can tell. After the procedure is completed one arranges the materials into different groups again. They can be put into their appropriate places. Eventually they will be used once more and the whole cycle will then have to be repeated. However, that is part of life.

The assertion that this is about washing clothes in a washing machine suddenly supplies a context that makes the passage completely meaningful.

Two recent studies of the effect of context in verbal processing are those by Frederickson (1975) and Anderson and Ortony (1975). Both presented evidence that indicates contexts strongly influence the interpretation of verbal passages, a fact that is a problem for current semantic network theories that assume fixed hierarchical relationships among concepts.

Earlier work with verbal material includes that of Bransford and Franks (1971) which indicates that the learner does not remember individual sentences verbatim from the stimulus materials but rather constructs meaning from the context that the sentence was presented in.

Similar effects of context have been found for pictorial material as well. Paris and Mahoney (1975) investigated the effects of context on recognition by children. In this study, the subjects were presented with either 3 sentences or 3 corresponding pictures that formed a story, where 2 of the items were "premise propositions" and one was a filler item. Three concepts or relationships were of interest: the two assertions of the premises and the implied relationship about the subject in the second premise. For example, the 3 sentences (or their pictorial equivalents) might be:

1) The box is to the right of the tree. (premise)
2) The chair is on top of the box. (premise)
3) The tree is green and tall. (filler)

The four test items for this example would be:

4) The box is to the right of the tree. (true premise)
5) The box is to the left of the tree. (false premise)
6) The chair is to the right of the tree. (true premise)
7) The chair is to the left of the tree. (false premise)

The test results showed that the children mistakenly identified the "true inferences" as items that they had seen during acquisition. The authors concluded that the results indicate that children do not store pictures as static or eidetic copies but construct sequential relationships into unified representations.

Discussion

The tantalizing glimpses of right and left cerebral hemisphere functions, of integrative processes between hemispheres, and of hemispheric interrelationships with the motor system, hold the promise of even more exciting discoveries in the future, as well as already having implications for training and education. These studies support Attneave's (1974) ideas about analog and digital representational processing systems, reviewed in the preceding report (Rigney and Lutz, 1974). Additionally, they indicate that the orienting tasks that are used, as well as the nature of the stimulus material, are of great importance in influencing right and left hemispheric processing. The studies of chimerical imagery in split-brain patients clearly illustrate this. When the task is appropriate for left hemisphere processing, the half of a symmetrical image, say a "face" composed of right and left halves of two different faces, that is seen by the right eye, is reported by the S as a complete face. When the task is appropriate to the right hemisphere, the different half-face projected to the left eye is the basis for the construction of a complete face in the mind's eye. (Ss gave no indication that they had seen the stimuli as "anything but complete and regular." Nebes, 1974, p. 11). When split-brain subjects were required to make pointing responses with their right <u>or</u> left hand to the correct item in an array of complete stimuli, they picked out the face whose half was shown in the left visual field and seen by the right hemisphere. In the same situation, when required to name or to verbally describe the stimulus, they picked the (different) face whose half was projected to the right visual field and seen by the left hemisphere.

The results with split-brain patients suggest that perception is a constructive process, as Neisser (1966) claimed, and that <u>what</u> is constructed is influenced by the task imposed at the time of construction. Is this an effect of selective attention or is it a more fundamental process? The fact that the Ss thought they saw one complete face when one half of two different faces reached each hemisphere seems to implicate more fundamental processes than selective attention, as this is ordinarily conceived. But the question of how selective attention, which is thought of as a unitary process, is managed between the dual-processing systems of the two hemispheres is another mystery. Again, there are tantalizing clues in this split-brain work. In two patients studied, the right hemisphere could have the left hand write a word that it had been shown. But it could not name that word. On some trials, the left hand began to reproduce the correct word, then stopped, and finished with letters appropriate to an incorrect guess apparently made by the left hemisphere, which the subject then verbalized. This suggests a relationship between selective attention and the dominant (left) hemisphere, although what is called attention may be a complex of processes originating and controlled at subcortical levels. (See Pribram and McGuinness, 1975, for a review of neurophysiological and psychophysiological data on attention).

In Geschwind's studies of apraxias in patients suffering from the callosal disconnection syndrome, if the orienting task was stated as a verbal command, the S could not carry it out with his left arm, but could execute the task with his right arm. If, instead of giving a verbal command the examinee performed the act himself, the patient could imitate the act with his left hand. This, we believe, is a highly significant point for instructional technology. The right hemisphere in these patients could "observe and imitate" correctly even though verbal commands, understood in the left hemisphere, could not reach it because of the lesion.

Perhaps, "observing and imitating" is a more direct way to learn how to perform that bypasses verbal encoding and decoding processes in the left hemisphere. Observation and imitation must be an important kind of learning not only among other social animals lacking highly developed language skills, but also in humans (e.g., see Bandura, 1969).

A review of the functions of the two cerebral hemispheres by Wittrock, Jerison, Gazzaniga, Nebes, Krashen, and Bogen, (1975) discusses implications for education. Bogen's summarizing statement about right and left hemisphere functions is the most memorable. He suggested that "each hemisphere represents the self and the world in complementary mappings: The left mapping the self as a subset of the world and the right mapping the world as a subset of the self." (p. 27).

These theorists pointed out the lopsidedness of modern education's emphasis on verbal processing. Wittrock reviewed the historical significance of imagery and its impact on learning and memory from the Greek poet Ceos (556-486 B.C.) and his system for improving memory, through the middle ages in which most of the populace was illiterate. He discussed the pedagogical value of imagery in architecture, suggesting that the intellectual and spiritual leaders of the times used these forms of imagery on and in churches to help teach the general ideas of the Christian religion.

The principal conclusion of Wittrock's review of hemispheric specialization that the functions of the right hemisphere have been neglected in modern education, agrees with Sperry's conclusion (1973):

> "The main theme to emerge from the foregoing facts is that there appear to be two modes of thinking, verbal and nonverbal, represented rather separately in left and right hemispheres, respectively, and that our educational system, as well as science in general, tends to neglect the nonverbal form of intellect. What is comes down to is that modern society discriminates against the right hemisphere."

The laboratory studies of imagery versus verbal processing, reviewed above, confirmed the existence of two processing systems, and contributed detailed evidence of the differences between the two systems, within the framework of traditional experimental psychological paradigms, in which relatively simple stimulus items, short exposure times and retention intervals, and verbatim recall tests are used.

The information about right hemisphere functions, reviewed above, suggests that the information processing functions of the right hemisphere might, properly coupled to animated interactive graphics displays of visual analogies, lead to better comprehension of the austere abstractions of science and technology, compared to purely verbal description.

The serial process of verbal description becomes cumbersome for describing complicated processes. Kammann (1975) reviewed a series of investigations for the comprehensibility of printed instructions, and has found that the results suggest a rule of thumb: Printed instructions will be understood by their intended readers only two-thirds of the time on an average. Perhaps more to the point, the reader need only find and read the nearest verbal description of how an NPN or a PNP transistor works to feel the need for a better way. For current examples of better ways, in which the usefulness of animated interactive graphics is being explored in the ongoing educational environment, see Bork (1973, 1975). For an outstandingly successful application of the effects of mental imagery on recall of words in an educational environment, see Atkinson and Raugh (1975).

IV. THE DESIGN OF THE STUDY

Purpose:

The combination of the plasma panel and the touch panel in the PLATO IV terminal is truly a magic slate! Touching a spot on this magic slate can initiate all kinds of events; diagrams can be made to appear, to move, to disappear; questions can be answered; instructional scheduling can be changed. In fact, the list is limited only by the ingenuity of the programmer.

How may this magic slate be used for instruction? Many of its advantages are quite clear. For example, pointing responses are much simpler, faster, and less error-prone than typing responses on a keyboard. The unique features this terminal offers for studying imagery is animated interactive graphics. Static pictures can be shown more inexpensively by a slide projector. Moving pictures can be shown more inexpensively by a movie projector. But these devices do not have interactive capabilities.

Method and Materials.

Two experimental conditions were developed as two different lessons explaining the concepts of electrochemistry involved in a simple primary cell: 1) the imagery condition, in which the surface-structure of the stimulus material was a mixture: a verbal statement of a concept followed by an animated graphics illustration. In the verbal condition, a concept was introduced by a verbal statement, but this was followed by a verbal explanation. Also, during each lesson, the structure of a simple battery was gradually built up by the addition of components, until the battery began to generate current through a wire, lighting a light bulb. In the imagery version of the lesson, this cumulative build-up was visible as a diagram showing electrodes, container, electrolyte, etc. In the verbal version, all this was described verbally. In both versions, the student interacted with the system through the touch panel.

One recognition and three recall tests were the main dependent variables. All were automatically administered by the PLATO IV system. The recognition test presented some of the surface-structure elements that were in the lesson to assess the S's recognition memory.

The recall tests were criterion-referenced tests that were developed to assess the degree to which the learning objectives had been attained.

The set of instructional objectives was written following the approach suggested by Gronlund (1970) in which a general instructional objective is stated and then defined in terms of some specific behaviors that are expected of the student at the end of the instruction. The objectives were organized hierarchically from simple to more complex learning outcomes in accordance with Bloom's taxonomy (1956). In this way it was possible to assess more simple outcomes such as knowledge of the facts presented during instruction as well as higher level outcomes such as ability to apply the information given in the lesson to a novel situation. Each test contained 20 items and corresponded to one of three levels of learning outcomes: knowledge, comprehension, and application.

A test specifications array was constructed so that the objectives could be related to the subject-matter concepts and test items could be referenced accordingly.

The effects of the treatments on student attitude were assessed using semantic differential scales to assess affect toward the lesson, and an attitude questionnaire, following the Fishbein approach, to assess the component beliefs and their valuations.

This approach to attitude measurement was used to help determine not only whether the students receiving the imagery treatment had a more positive affect toward it but also what specific beliefs they held about that treatment.

As Osgood, Suci and Tannenbaum (1957) point out, the semantic differential is not some kind of specific "test" having some definite set of items. It is rather a highly "generalizable technique of measurement" which must be adapted to the requirement of each research problem to which it applied. In this case, the objective was to measure the degree of positive or negative affect toward a CAI lesson on PLATO. Ten scales were developed for three concepts--the system itself, a tic-tac-toe game administered by the system, and the instructional lessons. The first two concepts--machine and tic-tac-toe game--were included to provide supplementary information about the learning environment. Four of the ten scales were selected because they load on the semantic differential evaluative dimension. (Osgood, Suci, and Tannenbaum, 1957). The other scales were selected because they were judged to be especially relevant to a CAI lesson. The subjects' responses to all ten scales were subjected to principal components analysis and (varimax) rotation. The purpose of this procedure was to identify the simple factor structure and to relate it to Osgood <u>et al</u>,'s evaluative dimension.

The other technique to assess attitude was based on Fishbein's (1965) theory of attitude formation. The attitude scores (factor scores) yielded by the Fishbein technique were correlated with the semantic differential factors to relate the two results. The Fishbein measute of attitude is:

$$\text{Attitude} = \sum_{i=1}^{N} B_i A_i$$

where B_i = the strength of the belief "i" about the object;

A_i = the evaluative aspects of B_i, that is, the evaluation of X_i--its goodness or badness; and

N = the number of beliefs

For validation of the basic algebraic assumptions of the model; multiplicative $B_i A_i$, powers assumed to be 1, summation over products of $B_i A_i$ etc., see Bettman, Capon, and Lutz; (1975a, 1975b).

The expected outcome of the attitude measures was that the imagery group would have a more positive affect toward the lesson than the group receiving the verbal only treatment.

A one-page set of instructions was developed for the subject on how to use the 7-point scales. The total attitude instrument, then, consisted of the instruction page, the semantic differential scales, and the Fishbein attitude questionnaire.

This study included a number of other individual difference measures. Measures of CLEM (Conjugate Lateral Eye Movement), spatial ability, verbal ability, handedness, and prior experience with the subject matter were obtained. These variables were included to explore possible aptitude by treatment interactions.

To measure CLEMS, lateral eye movements immediately following thought-provoking questions were observed by the questioner. A set of 20 questions was developed to elicit right or left eye movements. Ten of the items, designed to elicit verbal processing, were proverbs taken from the Home Book of Quotations (1968). The student was required to verbally explain the meaning of each proverb. The other ten items were questions designed to elicit spatial processing. An example is "How many windows are there in your house or apartment?" The questioner faced the subject but asked both verbal and spatial questions in order to discriminate any subjects who do change direction of eye movements in response to different types of questions.

Procedures

Forty undergraduate college students in an introductory psychology course chose to participate in this experiment to fulfill a course requirement. Subjects were run individually during the two sessions of the experiment. The sequence of events was as follows: (1) the Paper-Folding Test was administered; (2) the twenty verbal and spatial questions were administered and lateral eye-movements were recorded; (3) the subject began using PLATO IV, beginning with a short introduction on how to interact with the system, which included a short game of tic-tac-toe. (4) The subject took one of the versions of the battery lesson, determined by random assignment. (5) The instructional sequence was followed by the recognition test. (6) Three recall tests were administered. (7) The attitude questionnaire was administered off-line.

The second session was scheduled one week after the first so that delayed retention could be assessed. During this session, the subjects repeated the three levels of recall tests.

Results

Recognition and Recall Tests. Differences between the two treatment groups were found on all learning outcome measures. Tests of significance were: recognition test; t (38)=2.03, $p < .05$) recall tests; knowledge (t (38)= 2.49, $p < .02$); comprehension (t (38)=1.73; $p < .10$); and application (t (38)= 2.53; $p < .02$). The means, presented in Table 1, differed in the predicted direction, with subjects in the imagery group performing better on all tests. The largest difference between means was observed on the application test.

Only 75 percent of the students in the imagery group, and only 55 percent of the students from the verbal group, returned the following week for the delayed retention test. (The laboratory is approximately ¼ - ½ mile from the Campus.) This difference agrees with other data indicating that the animated graphics lesson was more attractive to the student. However, likely differential biases between these samples precluded analysis of the data.

Table 1

Summary of Means and Standard Deviations
for Learning Outcomes

Treatment Group	Recognition Test		Recall Subtests					
			R_1 Knowledge		R_2 Comprehension		R_3 Application	
	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD
Imagery (N=20)	11.50	(1.43)	14.95	(1.82)	11.85	(3.36)	11.05	(4.67)
No Imagery. (N=20)	10.50	(1.67)	13.35	(2.32)	9.75	(4.27)	7.95	(2.93)

Attitudes. The Fishbein attitude questionnaire discriminated between the two groups, as shown in Table 2. ($t(38) = 9.28$, $p < .0001$). The semantic differential factor scores on the attitude questionnaire will be discussed later. Correlational analysis revealed no within-group correlations between the Fishbein scores and recall tests R_1, R_2, or R_3, indicating that attitude was not related to amount learned. Individual items of the questionnaire were analyzed to reveal the probable sources of this overall attitudinal difference. As indicated in Table 4, most evaluative items of the form "In general, a lesson that possess this characteristic is good/bad" were scored similarly by both groups. But, the groups had very different beliefs about the characteristics of the lessons. Items (2,4,6,8, and 10) that refer to the characteristics of external imagery were rated most differently by the two groups.

Table 2

Summary of Means and Standard Deviations for Attitude and Semantic Differential Data

Treatment Group		Fishbein Attitude Questionnaire	Semantic Differential Factor Scores: Lesson		Machine		Game	
			Fac I	Fac II	Fac I	Fac II	Fac I	Fac II
Imagery	$\bar{X}$	62.00	-.01	.35	-.04	.24	.02	.01
(N=20)	SD	(18.50)	(.86)	(.69)	(121)	(.60)	(195)	(1.00)
No-Imagery	$\bar{X}$	-.1400	.01	-.50	.04	-.17	-.02	.05
(N=20)	SD	(31.36)	(1.00)	(.95)	(.60)	(.92)	(.91)	(.86)

Responses to item number 4 suggest that students who took the verbal version of the lesson evidently did not feel that it caused them to visualize how a battery works. The students in the imagery group thought that the animated graphics did help them to do this. This may have some bearing on the fact that these students did better on the application recall test. The factor loadings of the semantic differential scales on two rotated

Table 3

Summary of Factor Loadings for Semantic Differential Scales for the Lesson (Data from both Groups Combined) on Two Varimax Factors

Scale	Factor I	Factor II
good-bad	.63	.58
appropriate-inappropriate	.67	.42
sensible-foolish	.64	.47
adequate-inadequate	.67	.19
satisfying-disatisfying	.65	.49
suitable-unsuitable	.68	.32
worthy-unworthy	.68	.08
fun-dull	.25	.87
interesting-boring	.32	.66
pleasant-unpleasant	.19	.83
Eigenvalues	5.38	.87

Table 4

Mean Ratings of Beliefs and Valuations
by Treatment Group (N = 20)

Items		Imagery $\bar{X}$	Imagery (sd)	Non-Imagery $\bar{X}$	Non-Imagery (sd)	t	p
1. This lesson gave helpful examples:	Agree/Disagree	1.60	(1.60)	.5	(1.93)	1.96	.06
In general, giving helpful examples in a lesson is:	Good/Bad	2.75	(.44)	2.85	(.37)	-.78	NS
2. This lesson presented information using pictures:	Agree/Disagree	2.65	(.59)	-2.70	(.92)	21.89	.001
In general lessons that present information pictorially are:	Good/Bad	2.60	(.50)	2.35	(.99)	1.01	NS
3. This lesson provided helpful feedback:	Agree/Disagree	1.00	(2.00)	-.25	(2.00)	1.98	.06
In general lesson that provide helpful feedback are:	Good/Bad	2.8	(.41)	2.3	(1.17)	1.80	.10
4. This lesson caused me to "visualize" in my head how a battery works:	Agree/Disagree	1.85	(1.39)	-.80	(2.26)	4.47	.001
In general, lessons that cause the student to "visualize" information are:	Good/Bad	2.9	(.31)	2.75	(.55)	1.06	NS
5. This lesson taught the interrelationship between the parts of a battery:	Agree/Disagree	2.3	(.86)	2.0	(1.52)	.77	NS
In general teaching the interrelationships between the parts of some whole is:	Good/Bad	2.8	(.52)	2.3	(1.12)	1.80	NS

Table 4 (Cont'd)

Items		Groups				t	p
		Imagery		Non-Imagery			
		$\bar{X}$	(sd)	$\bar{X}$	(sd)		
6. This lesson gave visual examples:	Agree/Disagree	2.8	(.52)	-1.95	(1.70)	11.95	.001
In general, lessons that give visual examples are:	Good/Bad	2.9	(.31)	2.5	(1.00)	1.71	NS
7. This lesson gave useful information after touch responses:	Agree/Disagree	2.55	(.60)	.55	(2.37)	3.66	.001
In general, lessons that give useful information after touch responses are:	Good/Bad	2.15	(1.27)	2.15	(1.23)	.00	NS
8. This lesson used visual aids:	Agree/Disagree	2.8	(.52)	-1.35	(2.11)	8.54	.001
In general, lessons that use visual aids are:	Good/Bad	2.9	(.31)	2.4	(.99)	2.16	.06
9. This lesson provided concrete models for abstract concepts:	Agree/Disagree	2.25	(1.37)	-.9	(2.05)	5.71	.001
In general, lessons that provide concrete models for abstract concepts are:	Good/Bad	2.55	(1.40)	2.15	(1.09)	1.01	NS
10. This lesson had pictorial animation:	Agree/Disagree	2.75	(.72)	-2.85	(.67)	25.46	.001
In general, lessons that provide pictorial animation are:	Good/Bad	2.45	(1.15)	1.55	(1.43)	2.19	.05

factors are shown in Table 3. Since the good-bad dimension, also used in the Fishbein attitude questionnaire, had moderately high loadings on both factors, they provide useful interpretive information for the Fishbein data. Means and SD's of factor scores for each of the experimental groups were presented in Table 2. The two groups clearly differ with respect to these factor scores on Factor II ($t(38) = 3.24$, $p < .01$), which has its highest loadings on the fun-dull, pleasanteness-unpleasanteness, and interesting-boring scales. This result indicates that the group taking the verbal lesson using no graphics found it to be less fun, less interesting, and less pleasant than was the case for the group that took the animated graphics lesson.

Factor I loadings, highest on good-bad, appropriate-inappropriate, sensible-foolish, adequate-inadequate, etc. (Table 3), yielded factor scores that were essentially the same for the two treatments. The Eigenvalues (Table 3) indicate that Factor I accounted for most of the variance in the semantic differential scores.

Factor scores for the other two concepts--the PLATO machine and the game--were not significantly different. Means and standard deviations are presented in Table 2 and indicate that although the groups differed in their affect toward the treatment they had similar attitudes toward the PLATO machine itself as well as the tic-tac-toe game that they interacted with before the instructional treatment.

Individual Differences. Aptitude test scores and other individual difference data are summarized in Table 5. Comparisons between the treatment groups on the variables of sex, SAT, Paper-Folding Test, and prior experience revealed no statistical differences. The groups appear to be equivalent on these dimensions.

Table 5

Summary of Means and Standard Deviations for Individual Difference Variables by Treatment Groups

Variables	Group			
	Imagery (N=20)		No Imagery (N=20)*	
	$\bar{X}$	SD	$\bar{X}$	SD
Paper Test	13.09	(8.92)	13.39	(9.18)
SAT: Verbal	46.90	(9.06)	45.56	(12.17)
SAT: Math	54.65	(10.42)	51.50	(14.17)
College Chemistry[a]	1.60	(.50)	1.8	(.41)
High School Chemistry[b]	1.60	(.88)	1.95	(.95)
College Physics[c]	1.90	(.31)	1.90	(.31)
Handedness[d]	1.15	(.37)	1.15	(.37)
Sex[e]				

* Except for SAT Math & SAT Verbal, N=18.

a. 1 = yes, 2 = no

b. 1 = none, 2 = 1 yr. 3 = more than 1 yr.

c. 1 = yes, 2 = no

d. 1 = right, 2 = left

e. 1 = female, 2 = male

Table 6

Matrix of Intercorrelations Among Some Variables for the Imagery Group*

Variables	R_1	R_2	R_3	SATV	SATM	PFT	AF	ASD1	ASD2	EM
Recall 1 Knowledge		.53	.51	.64	.30	.22	-.31	-.09	.23	-.48
Recall 2 Comprehension			.79	.71	.57	.63	-.09	.44	.07	-.14
Recall 3 Understanding				.59	.51	.46	.11	.53	.21	-.04
SAT: Verbal					.72	.76	-.22	.34	.07	.20
SAT: Math						.77	-.11	.52	.01	-.02
Paper Folding Test							-.11	.49	.10	.08
Attitude - Fishbein								.45	.14	.18
Attitude - SD - Factor 1: Suitable									.39	.47
Attitude - SD - Factor 2: Fun										.09
Eye Movement										-.23

* N = 20; values of r [illegible]0 are significant at the .10 level.

Table 7

Martix for Intercorrelations Among Some Variable for the Verbal Only Group*

Variables	R_1	R_2	R_3	SATV	SATM	PFT		ASD1	ASD2	EM
Recall 1 Knowledge		.68	.85	.16 (18)	.43 (18)	.43	.17	-.12	-.01	-.09 (19)
Recall 2 Comprehension			.77	.29 (18)	.46 (18)	.46	.19	-.11	-.00	.17 (19)
Recall 3 Understanding				.34 (18)	.63 (18)	.58	.14	-.08	.02	.16 (19)
SAT: Verbal					.74 (1[illegible])	.67 (18)	.20 (18)	.30 (18)	.20 (18)	.07 (19)
SAT: Math						.84 (18)	.15 (18)	.14 (18)	.23 (18)	-.21 (19)
Paper Folding Test							.25	.16	.26	-.25 (19)
Attitude-Fishbein								.46	.53	-.01 (19)
Attitude - SD - Factor 1: Suitable									-.02	.10 (19)
Attitude - SD - Factor 2: Fun										.10 (19)
Eye Movement										.07

* N = 20, except where specified in parenthesis. For N = 20, values of r ≥ .30 are significant at the .10 level. For N = 19, values of r ≥ .31 are significant at the .10 level. For N = 18, values of r ≥ .31 are significant at the .10 level.

Individual difference variables were correlated with the learning and attitude outcomes and with each other. These relationships are summarized for the imagery group in Table 6, and for the verbal group in Table 7. These correlations reveal slightly different patterns of aptitude-by-treatment (ATI) correlations between verbal and imagery groups.

Although the differences between the groups are interesting, interpretation would be highly speculative. Cronbach (1975) has discussed problems associated with such ATI analyses. Similarly, there is some evidence in Tables 6 and 7 for a weak ATI between the eye-movement data and the Fishbein attitude questionnaire: $r = .47$ for the Graphic Group vs $r = -.10$ for the Verbal Group.

The eye-movement score was obtained by summing the scores for each of the 20 items. The scoring procedure for each of twenty items on the eye-movement test was as follows: 1 for a right-movement, 2 for no lateral movement, and 3 for a left movement. The EM scores, then, ranged from 60 for a perfect left-mover to 20 for a perfect right-mover. The positive correlation between EM and the attitude variable in the imagery group indicates that left-movers (suggestive of more reliance on right hemisphere processing) liked the treatment with external imagery better. These kinds of relationships are worthy of consideration for further research.

In Table 8, we see that the Paper-Folding Test correlated highly with the math and the verbal SAT tests. A result of this nature should not be surprising. The dual-processing systems in the right and left hemispheres, reviewed above, are both available to normal subjects, and most non-trivial information-processing tasks probably require some mixture of both types of processing.

TABLE 8

Matrix of Intercorrelations Among all Variables for all Groups*

	Sex	R_1	R_2	R_3	SATV	SATM	PFT	AF	ASD1	ASD2	EM
Sex	.	.39	.27	.12	.24 (38)	.43 (38)	.27	-.08	-.24	-.05	-.32 (39)
Recall 1, Knowledge			.66	.68	.37 (38)	.39 (38)	.31	.32	-.10	.22	-.06 (39)
Recall 2 Comprehension				.76	.47 (38)	.51 (38)	.51	.28	~~.10~~	.14	.00 (39)
Recall 3 Understanding					.45 (38)	.52 (38)	.45	.37	.24	.25	.06 (39)
SAT: Verbal						.73 (38)	.71 (38)	.09 (38)	.32 (38)	.16 (38)	-.11 (37)
SAT: Math							.80 (38)	.14 (38)	.29 (38)	.20 (38)	-.10 (37)
Paper Folding Test								.05	.31	.17	.10 (39)
Attitude-Fishbein									.24	.57	-.04 (39)
Attitude-SD Factor 1-Suitable										.11	.10 (39)
Attitude-SD Factor 2-Fun											-.14 (39)
Eye-movement											

* N = 40, except where indicated in parenthesis. For N = 40, values of r ≥ .26 are significant at the .05 level. For N = 40, values of r ≥ .27 are significant at the .05 level.

Stepwise regression analysis of these relationships between recall and the aptitude variables is given in Table 9. The math section of the SAT appeared to be the best predictor of knowledge and application recall items, the Paper Folding Test the best predictor for the comprehension test.

Table 9

Summary of Multiple Correlations using SAT Scores and Paper Folding Test to Predict Learning Outcomes

N = 38

Dependent Variable	Predictor Variables	Step-wise Regression R	R_2
Recall 1 Knowledge	SAT: Math + SAT: Verbal + Paper Folding Test	.39 .41 .42	.16 .17 .17
Recall 2 Comprehension	Pape Folding Test + SAT: Math + SAT: Verbal	.51 .54 .55	.26 .29 .30
Recall 3 Application	SAT: Math + SAT: Verbal	.52 .53	.27 .28

DISCUSSION

The principal outcomes of this first study were that the lesson in which animated, interactive graphics supplemented verbal description resulted in somewhat higher scores on recall tests of knowledge, comprehension, and application, and that the students found this lesson to be more interesting. The bigger differences observed on the three recall tests, in which students had to generalize their knowledge of how a battery works, could have been an effect of the supplementary graphics in this lesson. Factors such as dual-coding, spatial topography, and interaction with graphics could have facilitated a better understanding of the concepts, constituents, and principles underlying simple batteries. This outcome generally agrees with information in the literature.

The moderate correlation between eye-movement data and attitude data for the imagery group (.47) versus essentially no correlation (-.10) between these variables in the verbal group, is interesting. However, the difference was not large enough to warrant an aptitude-by-treatment interaction analysis.

First studies always raise more questions than they answer. In most of the literature describing positive effects of imagery on learning, the task usually involves learning simple material, such as trigrams or nouns, and the treatment difference usually is produced by instructions to use mental imagery. Peterson's (1975) results with spatial matrices are an exception to the outcome of this common approach. His subjects who looked at external images of the matrices did better on short-term recall than subjects who were instructed to construct mental images of the matrices while listening to tapes which described their contents.

However interesting these results are, it is doubtful that they can be generalized to the much more complex subject-matter, learning conditions, and recall tests, characteristic of training and education. Instructions to students to image, while learning more complex subject-matter, encounter certain difficulties that were discussed in the earlier report in this series. It would be preferable to so arrange conditions that subjects would be forced to use mental imagery during learning. The results of this study suggest that the external imagery that was supplied did stimulate mental imagery. However, more powerful procedures are needed to force students to elaborate their own imagery from that which is supplied to them. These are likely to fall under the heading of content mediators, as discussed in earlier reports.

It is desirable to have better indicators of when subjects are generating mental imagery. Verbal report is insufficient evidence. Possibilities for using evoked potentials for this purpose were suggested by Calloway's work, noted above. These are being investigated.

Finally, it is desirable to relate imagery processing with current theories of the structure of long term memory, now primarily based on neo-associationism applied to verbal processing. [illegible] maintain that the basic processes in long term memory are [illegible] for both imagery and verbal processing. This may or may not be so; certainly the evidence for two coding systems must be handled by propositional theories. Perhaps, the more important question for education and training is how to organize the mixture in ways that will be more effective than those suggested by common practices.

REFERENCES

Anderson, R.C. and Artony, A. On putting apples into bottles--a problem of polysemy. Cognitive Psychology, 1975, 7, 167-180.

Atkinson, R.C. and Raugh, M.R. An application of the mnemonic keyword method to the acquisition of a Russian vocabulary. Journal of Experimental Psychology: Human Learning and Memory, 1975, 104, 126-133.

Atkinson, R.C., and Shiffrin, R.M. Human memory: A proposed system and its control processes. In K.W. Spence and J.T. Spence (Eds.), The Psychology of Learning and Motivation: Advances in Research and Theory, Vol. 2. New York: Academic Press,1968, 89-195.

Attneave, F. How do you know? American Psychologist, 1974, 29, 493-499.

Bakan, P. Hypnotizability, laterality of eye movements, and functional brain assymetry. Perceptual and Motor Skills, 1969, 28, 927-932.

Bakan, P. The eyes have it. Psychology Today, 1971, 4, 64-69.

Bandura, A. Principles of Behavior Modification, New York: Holt, Rinehart, and Winston, Inc., 1969.

Bettman, J.R., Capon, N. and Lutz, R.J. Multivariate measurement models and multiattribute attitude theory: A test of construct validity. Journal of Consumer Research, 1975, 1, 1-15.

Bettman, J.R., Capon, N. and Lutz, R.J. Cognitive algebra in multiattribute models. Journal of Marketing Research, 1975, 12, 151-164.

Bever, T.G. & Chiarello, R.J. Cerebral dominance and musicians and non-musicians. Science, 1974, 185, 537-539.

Bloom, B.S. (Ed.), Taxonomy of Educational Objectives. Handbook I: Cognitive Domain. New York: David McKay Co., Inc., 1956.

Bogen, J.E. Educational aspects of hemispheric specialization. UCLA Educator, 1975, 17, 24-32.

Bork, A.M. Effective computer use in physics education. American Journal of Physics, 1975, 43, 81-88.

Bower, G.H., Karlin, M.B. and Dueck, A. Comprehension and memory for pictures. Memory and Cognition, 1975, 3, 112-117.

Bransford, J.D. and Franks, W. The abstraction of linguistic ideas. Cognitive Psychology, 1971, 2, 331-350.

Bransford, J.D. and Johnson, M.K. Considerations of some problems of comprehension, In W.G. Chase (Ed.), Visual Information Processing, New York: Academic Press, 1973.

Byrne, B. Item concreteness vs spatial organization as predictors of visual imagery. Memory and Cognition, 1974, 12, 53-59.

Calloway, E. and Harris, P.R. Coupling between cortical potentials from different areas. Science, 1974, 183, 873-875.

Cronbach, L.J. Beyond the two disciplines of scientific psychology. American Psychologist, 1975, 30, 116-127.

Dewing, K. and Hetherington, P. Anagram solving as a function of word imagery. Journal of Experimental Psychology, 1974, 102, 764-767.

Fishbein, M. A consideration of beliefs, attitudes, and their relationships. In I.D. Steiner and M. Fishbein (Eds.), Current Studies in Social Psychology. New York: Holt, Rinehart, and Winston, 1965.

Forbes, E.J. and Reese, H.W. Pictorial elaboration and recall of multi-list paired associates. Journal of Experimental Psychology, 1974, 102, 836-840.

Frederiksen, C.H. Effects of context-induced processing operations on semantic information acquired from discourse. Cognitive Psychology, 1975, 7, 139-166.

Gazzaniga, M.S. Review of the split brain. UCLA Educator, 1975, 17, 9-12.

Gazzaniga, M.S., and Hillyard, S.A. Language and speech capacity of the right hemisphere. Neuropsychologia, 1971, 9, 273-280.

Geschwind, N. Language and the brain. Scientific American, 1972, 226, 76-83.

Geschwind, N. The apraxias: Neural mechanisms of disorders of learned movement. American Scientist, 1975, 63, 188-195.

Gronhinger, L.D. The role of images within the memory system: Storage or retrieval? Journal of Experimental Psychology, 1974, 103, 178-180.

Gronlund, N.E. Stating Behavioral Objectives for Classroom Instruction. London: McMillan Co., 1970.

Gur, R.E., Gur, R.C., and Harris, L.J. Cerebral activation, as measured by subject lateral eye movements, is influenced by experimenter location. Neuropsychologia, 1975, 13, 35-45.

Hacaen, H. and Ajuriaguerra, T. Left Handedness. New York: Grune and Stratton, 1964.

Hayes, J.R. On the function of visual imagery in elementary mathematics. In G.W. Chase (ed.), Visual Information Processing. New York: Academic Press, 1973.

Jenkins, J.J. Remember that old theory of memory? Well, forget it! American Psychologist, 1974, 29, 785-795.

Jerison, H.J. Evolution of the brain. UCLA Educator, 1975, 17, 1-8.

Kammann, R. The comprehensibility of printed instructions and the flowchart alternative. Human Factors, 1975, 17, 183-191.

Kimura, D. The asymmetry of the human brain. Scientific American, 1973, 228, 70-78.

Kinsbourne, M. Eye and head turning indicates cerebral lateralization. Science, 1972, 176, 939-941.

Krashen, S.D. The left hemisphere. UCLA Educator, 1975, 17, 17-23.

Lesgold, A.M. et al. The Role of Mental Imagery in Text Comprehension: Preliminary Studies. Learning Research and Development Center, University of Pittsburgh, 1974.

Madigan, S. Representational storage in picture memory. Bulletin of the Psychonomic Society, 1974, 4, 567-568.

Madigan, S. and Rouse, M. Picture memory and visual generation processes. American Journal of Psychology,

McNeil, M.R. and Hamre, C.E. A review of measures of lateralized cerebral hemispheric functions. Journal of Learning Disabilities, 1974, 7, 51-59.

Nebes, R.D. Hemispheric specialization in commissuratomized man. Psychological Bulletin, 1974, 81, 1-14.

Nebes, R.D. Man's so-called "minor hemisphere." UCLA Educator, 1975, 17, 13-16.

Neisser, U. Cognitive Psychology. New York: Appleton, 1966.

Norman, D.A., Gentner, D.R. and Stevens, A.L. Learning and Teaching. La Jolla, Calif.: Center for Human Information Processing, March, 1974.

Osgood, C.E., Suci, G.J. and Tannenbaum, P.H. The Measurement of Meaning. Urbana: University of Illinois Press, 1957.

Paivio, A. Language and knowledge of the world. Educational Researcher, 1974, 3, 5-12.

Paivio, A. and Begg, I. Pictures and words in visual search. Memory and Cognition, 2, 515-521.

Paivio, A. and Csapo, K. Picture superiority in free recall: Imagery or dual coding? Cognitive Psychology, 1973, 5, 176-206.

Paris, S.G. and Mahoney, G.J. Cognitive integration in children's memory for sentences and pictures. Child Development, 1975, 45, 633-642.

Pellegrino, J.W., Siegel, A.W., and Dhawan, M. Short term retention of pictures and words: Evidence for dual coding systems. Journal of Experimental Psychology: Human Learning and Memory, 1975, 104, 95-102.

Penfield, W. and Roberts, L. Speech and Brain Mechanisms. Princeton, N.J.: Princeton University Press, 1959.

Petersen, R.C. Imagery and cued recall: Concreteness or context. Journal of Experimental Psychology, 1974, 102, 841-844.

Peterson, M.J. The retention of imagined and seen spatial matrices. Cognitive Psychology, 1975, 7, 181-193.

Pribram, K.H., and McGuinness, D. Arousal, activation and effort in the control of attention. Psychological Review, 1975, 82, 116-149.

Rigney, J.W. Computer-aided instruction for teaching integrated task performance. Paper to be presented at IFIP, Marseille, France, Sept. 1975.

Rigney, J.W. and Lutz, K.A. CAI and Imagery: Interactive Computer Graphics for Teaching about Invisible Processes. Los Angeles: University of So. Calif. Behavioral Technology Laboratories, Jan. 1974. (Tech. Rep. No. 74.)

Salthouse, T.A. Using selective interference to investigate spatial memory representations. Memory and Cognition, 1974, 2, 749-757.

Salthouse, T.A. Simultaneous processing of verbal and spatial information. Memory and Cognition, 1975, 3, 211-225.

Snodgrass, J.G. and Antone, G. Parallel versus sequential processing of pictures. Journal of Experimental Psychology, 1974, 103, 139-144.

Sperry, R.W. Lateral specialization of cerebral function in the surgically separated hemispheres. In Mcguigan, F.J. (Ed.), The Psychophysiology of Thinking. New York: Academic Press, 1973.

Stevenson, B. (Ed.), The Home Book of Quotations, 10th Edition. New York: Dodd, Mead and Co., 1967,

Tversky, B. and Sherman, T. Picture memory improves with longer on time and off time. Journal of Experimental Psychology: Human Learning and Memory, 1975, 104, 114-118.

Weitan, W. and Etaughn, C. Lateral eye movements as related to verbal and perceptual-motor skills and values. Perceptual and Motor Skills, 1973, 36, 423-428.

Wittrock, M.C. The generative processes of memory. UCLA Educator, 1975, 17, 33-43.