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ABSTRACT

Eye movement analysis should provide a basis for differentiation of humans in terms of developed preference for certain kinds of visual presentations over other kinds. A study was conducted to examine this position. A total of 40 children from grades 8 through 12 participated as subjects. Each subject was presented with a synchronous audio-visual paired associate learning situation, with one group receiving pictorial representation and the other receiving print representation: in the picture condition, the subject viewed a picture of the objects, and in the verbal condition, a printed sentence identifying the objects. A pretest and posttest evaluated by means of an eye camera the subject's use of his eyes, recall tests were given at the end of each learning trial, several standard ability measures were administered, and demographics were obtained. Results showed that pictorial supported audio-visual associative learning is superior to printed word supported learning, and that adding eye movement variables to prediction equations using more conventional predictors greatly increases the amount of variance accounted for. (SH)

EYE MOVEMENT PREFERENCES AS INDIVIDUAL DIFFERENCES IN LEARNING FROM PRINT AND PICTURES

by

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Introduction

This study is aimed at adapting newly-developed eye movement technology for use in educational research. As such, evaluation in a relatively standard learning situation was deemed essential. The learning situation was selected from work done by Rohwer (1967). This experiment replicated the earlier study with the addition of information about individual differences in eye movement behavior during learning.

Eye movement patterns while viewing visual displays offering a choice between two object representation modes, picture and print, provided indices of preference for these representation modes as well as other indices of attention to visual information. Past research, especially the work of Norman H. Mackworth (1968) and A. L. Yarbus (1967), suggested that visual search pattern variables such as density, sequence, length, and total number of fixations; total fixation times by classes of stimuli; and frequency of fixation shift all had relevance for this study. Data relevant to all of these variables were collected, although the present analysis dealt only with those variables considered most important for this particular learning situation.

In general, an experiment can be improved by inclusion of additional variables under control. The major thrust of the present study, however, was developmental and exploratory. In order to concentrate upon the developmental aspects of the adaption to educational uses of the technology and procedures of eye movement behavior analysis, the decision was made to concentrate on only two

kinds of stimulus materials - pictorial and printed representations - as defined in the Rohwer study. The Rohwer learning task was chosen for its simplicity and relevance to meaningful learning.

> An alternative way (from standardized tests) to measure learning ability is that of observing the performance of children on tasks that themselves principally demand learning rather than the recall of what has been learned in the past. The strength of this alternative is that the assumption of equivalent previous opportunities for learning is unnecessary. (Rohwer, 1967, p. 10)

Research in the field of audio-visual education has not often reached clear conclusions. Dwyer (1967) explains that one reason for the difference in findings may be lack of equivalence in the content of the studies: "These studies seem to indicate that no valid comparison can be made unless the material equivalent in content appears in all of the media being compared."

Such an experiment was performed by William D. Rohwer in 1967. The experiment was designed to assess the effectiveness of different audio and visual representations in paired-associate learning. Learning was found more efficient with pictorial than with printed materials ($p < .01$). More than 32 per cent of the total criterion variance was associated with this factor. The results of Rohwer's study showed visual presentation of pictures of objects to be more effective than the visual presentation of printed names of the objects. Accepting the assumption that pictures are relatively realistic presentations, these findings support earlier research (Wimer and Lambert, 1959) that unmediated objects were better stimuli than printed names of the objects for learning trigram pairs.

General Background

Mackworth (1961) has stressed the need to appreciate human

behavior "as an on-going process with each discrete act dependent upon both previous and concurrent experiences as well as expectations of future possibilities for acting."

Travers (1964) provided an extensive review of literature on audio-visual information presentation and processing, indicating that attention has been studied until recently by introspection and that a new model which abandoned the traditional approach was developed in the 1950's by D. E. Broadbent. This approach was based upon an information theory model which ignores introspection and motor tasks, and concentrates on the perceptual aspects of attention. That is, the inputs are considered messages rather than stimuli to be measured in terms of simple physical quantities. An attempt to make the theory fit experimental data, Broadbent's theory posits a receptor's stage, a short-term storage bank, a filter for information selection, and a limited capacity single channel for serial information transfer into long-term storage.

Lunzer (1968), however, felt that Broadbent's theory over-emphasized the nature of the source of stimulation in the filtering process. He theorized that "the filtering of input is achieved by the pre-setting of the comparator system as a result of which it is predisposed to the recognition of privileged cue-combinations." That is, "channel selection is secondary to the pre-setting mechanism." Thus Lunzer infers that the comparative system often acts as a unified system so intake selection occurs both within as well as between sense modalities.

Saunders (1964) complained that Broadbent's model was lacking in its ability to deal with ongoing temporal processes. He suggested that it was appropriate for "a motionless subject with a fixated eye, who

awaits the arriving information." However, "the notion of steering is a necessary complement; it refers to the observation that the subject is able to decide from which sources he will select his information."

A Russian investigator, E. N. Sokolov (1963) has published a new approach to the relationship. Sokolov's model provides input control based on the ongoing processing of information. (See Figure 1.) It should be noted that Sokolov's model requires logically the prior acceptance of the organism's normal ability to create and store for future use neural models of the world as perceived. Miller, Galanter and Pribram (1960) call these models "plans." These models or plans in the organism are called up on receipt of new stimuli. The new perceptions are compared to the stored model or plan "templates" and new perceptions are ordered.

These more physiologically oriented approaches provide process-oriented feedback as perception-directing operators and past experiences become important to the organisms ongoing information-intake strategies. The strong implication is that preferential selection from the environment is normal to life.

In a cross-cultural study of visual perception, where the differences that were found were not thought to be "racial" differences but rather differences resultant from experience, Segall et. al. (1966) concluded:

> ...that to a substantial extent we learn to perceive; that in spite of the phenomenally absolute character of our perceptions, they are determined by perceptual inference habits; and that various inference habits are differentially

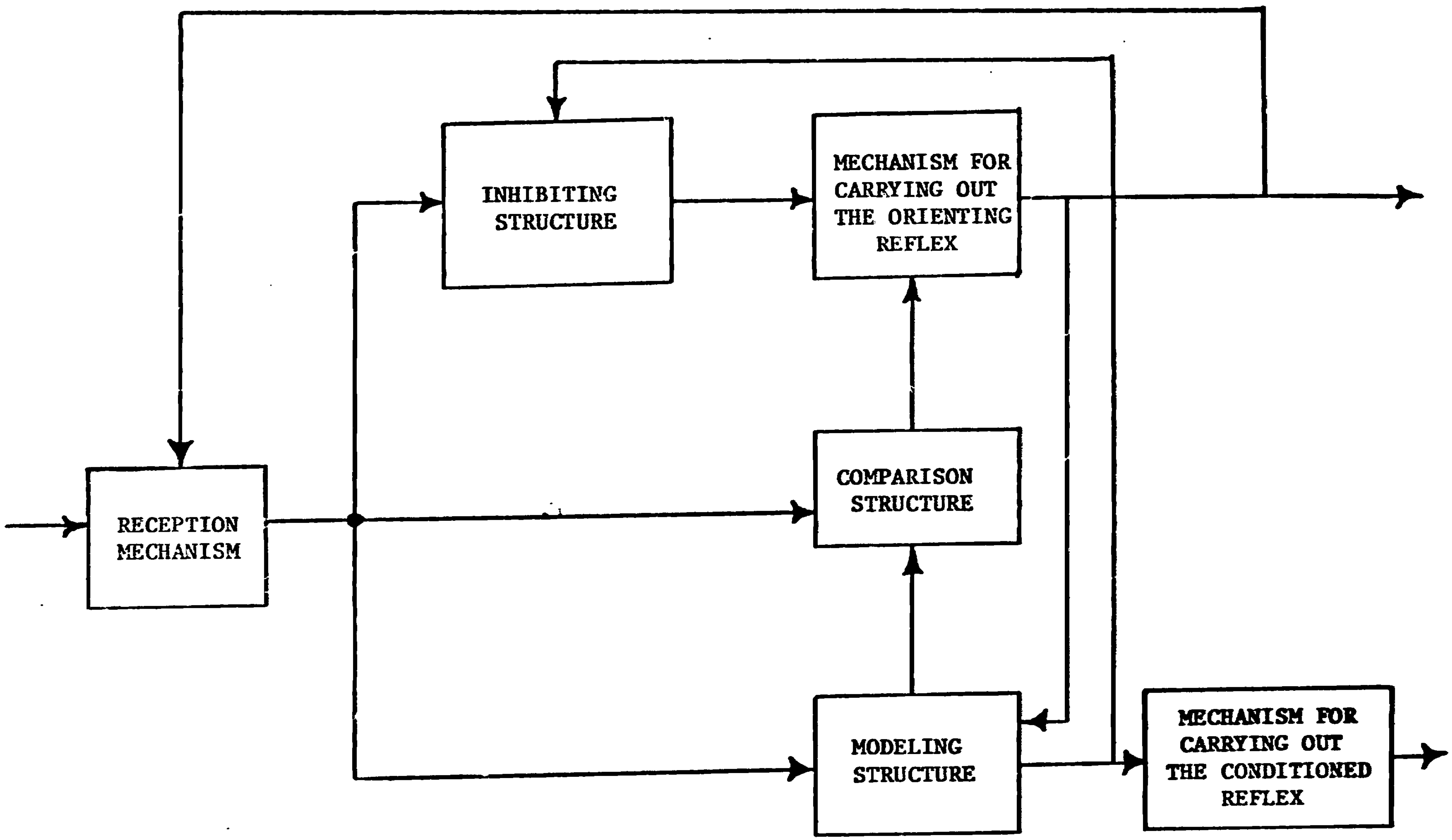


Figure 1 Structural schema of the orienting reflex (after Sokolov, 1969)

likely in different societies, for all mankind, the basic process of perception is the same; only the contents differ and these differ only because they reflect different perceptual inference habits. (p. 214)

Particularizing the discussion in terms of eye movement behavior, Yarbus (1967) summarized:

> The human eyes voluntarily and involuntarily fixate on those elements of an object which carry or may carry essential and useful information. The more information is contained in an element, the longer the eyes stay on it. The distribution of points of fixation on the object changes depending on the purpose of the observer, i.e., depending on the information which he must obtain, for the different information can usually be obtained from different parts of an object. The order and duration of fixations on elements of an object are determined by the thought process accompanying the analysis of the information obtained. Hence people who think differently also, to some extent, see differently. (p. 211)

Purpose of the Study

This study assumed that subjects will have built up a history of varying degrees of success and failure with different kinds of visual presentation modes when in interaction with materials of learning. Some modes of presentation thus become preferred. Consequently, given a choice, subjects control intake of visual information by directing their eyes more toward the preferred presentation mode areas in a visual display. This behavior was expected to be relatively stable. It was also expected that a measure of such behavior would predict greater learning efficiency in an experiment where the subject is provided the opportunity to use the favored presentation mode. The implications of such a finding for education would seem obvious.

Aptitude-Treatment Interaction. Cronbach (1957) has been concerned with the lack of coordination between experimental and correlational

psychology. Experimental psychology, on the one hand, has been interested in experimenter-generated between-treatment variation and has usually treated individual differences as "error variance." Correlational psychology, on the other hand, has maintained interest in already existing variation between individuals and groups for a given treatment usually ignoring the possibilities of treatment variation.

In Cronbach's words,

> In applied psychology, the two disciplines are in active conflict....The program of applied experimental psychology is to modify treatments so as to obtain the highest average performance when all persons are treated alike--a search, that is, for "the one best way." The program of applied correlational psychology is to raise average performance by treating persons differently--different job assignments, different therapies, different disciplinary methods....--and is utterly antagonistic to a doctrine of "the one best way..." (p. 678)

Cronbach argues for a marriage of the two:

> The organism which adapts well under one condition would not survive under another. If for each environment there is a best organism, for every organism there is a best environment. The job of applied psychology is to improve decisions about people. The greatest social benefit will come from applied psychology if we can find for each individual the treatment to which he can most easily adapt. This calls for the joint application of experimental and correlational methods. (p. 679)

Thus the "decision maker must determine what treatment shall be used for each individual or each group of individuals." This can be conceived in terms of maximizing the expected outcome or payoff. Cronbach, then has argued for increasing the payoff by seeking interactions between experimental treatments and aptitudes. Translating this into educational action, the objective becomes one of fitting the educational treatments to the individuals, or groups of

individuals, on the basis of any relevant differential variables that interact with the treatments. This procedure implies more than just investigation of main effects, it implies looking within the main effects, or lack thereof, for differential or even oppositely pitched ability--treatment relations. It is interesting to note that a lack of significance in a main effect could be the algebraic resultant of the summing of two inversely related yet statistically significant payoff relations between variables. With the increase of audio-visual learning devices and the pressures toward efficiency in education, the search for meaningful interactions between the several instructional media and the various learner abilities becomes important.

Eye movement analysis should provide a basis for differentiation of humans in terms of developed preference for certain kinds of visual presentations over other kinds of visual presentations, by quantifying the behavioral resultant of sensory control over visual intake of information to be learned. These quantifications could then be used to predict differential success with the several presentation modes in a standard learning situation.

Hypothesis I: In a synchronous audio and visual presentation, learning will be facilitated more by pictorial representation than by printed word representation.

This hypothesis follows from the Rohwer studies, where small but significant effects were obtained in the predicted direction of difference. As detailed below, the present experiment replicates the Rohwer study, using his original stimulus materials but with additional controls on potentially confounding variables. If the controls are

effective, greater differences should be obtained.

Hypothesis II: The interaction of presentation mode preference, as expressed by eye fixation variables, and presentation mode conditions on learning scores should be significant. That is, the pictorial preference as defined by fixation time should be positively related to performance under pictorial treatment and negatively related to performance under printed treatment. The reverse is predicted for printed word preference.

This hypothesis follows from the previous argument that eye movement fixations are physiological indicators of presentation mode preferences that have developed from past experience with such modes. This hypothesis implies non-parallel regression slopes although, considered with the first major hypothesis, not necessarily disordinal slopes within the scale range of the measurement instruments.

Hypothesis III: Prediction of learning success will be facilitated by adding eye movement variables to prediction equations based on more conventional ability predictors.

This follows from the general strategy of prediction improvement by inclusion of new variables related to the criterion while not related to other predictors. This exploratory hypothesis will test the unique contribution of eye movement instrumentation and analysis as predictor variables for learning treatments.

EYE CAMERA TECHNOLOGY

Visual attention experiments require accurate instrumentation for measuring the eye fixation and movement patterns of experimental subjects. The eye camera has been used for this purpose. Eye camera data show the number, duration, and location of eye fixations, and these data provide good indicators of attention (Gould and Schaffer, 1967). Saunders (1963) has written that eye movements "can be said to be the only instance in which 'shifts of attention' are clearly met. They take time and they can be measured." He concluded that "The application of eye movement recording therefore will provide a great aid to the analysis of the selective process."

Visual perception proceeds through a process of movement of the eyes. Even when we feel we are fixating stationary objects with a stationary gaze, the eyes are in motion. There are several classes of eye movements. One group includes drifts, tremors, involuntary saccades, and movements which accompany the motion of the head, or which are caused by pulsation of the blood or constant changes in the state of the lens or the size of the pupil. This group may be classified as micro movements in that they are imperceptible to the individual organism involved. These micro movements were not of interest in the present study for several reasons: 1) no immediate connection has been made theoretically with the learning process and 2) the observation of these effects was beyond the capabilities of the technology finally utilized in this study.

The second class of eye movement that has been studied is the macro movement - the saccatic character of eye movements. This important effect reflects the need for accurate pointing of the eyes,

to within one degree or so of the object of fixation. Studies by Yarbus (1967) and others dealing with perception of objects stationary relative to the retina indicate that visual perception must utilize the high resolution part of the fovea; when peripheral vision must be used for comparison purposes or information obtaining, relatively little success is realized. It has been shown experimentally that during the perception of stationary objects, when the head movement itself is not a contributing factor, there are only two states possible for the human eye: 1) a state of fixation or 2) a state of changing between fixations. This is the macro movement area.

Yarbus (1967) concludes that

> ...individual observers differ in the way they think and, therefore, differ also to some extent in the way they look at things...depending on the task in which a person is engaged, i.e., depending on the character of the information which he must obtain, the distribution of the points of fixation on an object will vary correspondingly, because different items of information are usually localized in different parts of an object. (p. 171)

Eye Movement Instrumentation

Mackworth (1962) developed the basic design for an eye camera apparatus that allows the experimenter to determine the eye fixation of the subject within one-degree accuracy out of a 20° by 20° field. Previous techniques have utilized Polaroid still-camera photography and direct television recording of eye movements. Any eye camera technique requires a stable relationship between the eye and the camera. This has been accomplished either by bracing the head to the camera or

attaching the camera to the head. In previous techniques an image of the visual field scanned needed to be introduced to the camera by mirrors as well.

One of Mackworth's (1967) earliest eye cameras recorded the reflection of a light off of the surface of the cornea superimposed on a photographic plate on an image of the visual display being examined by the subject. The calibration of this system was accurate to within one degree of arc. This system however required an uncomfortable bite bar and was relatively unnatural in terms of subject reaction. Subsequently, Mackworth (1968) has developed a reflection eye movement apparatus which recorded on film eye movements and the reflection of the visual display simultaneously by direct filming process. Due to the sensitivities of film, however, the display must be extremely bright in nature (Mackworth and Morandi, 1967). Figure 2 presents a drawing from a Mackworth photograph.

Instrumentation. The basic eye movement apparatus of the present experiment was based upon Mackworth's reflection apparatus. The present apparatus represented a refinement of the Mackworth machine using video tapes and a television camera as the recording instrument. This permitted recording under lower light conditions than typically could be used in a Mackworth device using motion picture film and so allowed the use of rear screen projection of stimuli. It also permitted a continuous recording from which different kinds of data reduction could be obtained and provided for the synchronous recording with the video of the audio experimental presentation used and real time audio responses by the subject. Thus, paper and pencil were not needed or used in this part of the experiment.

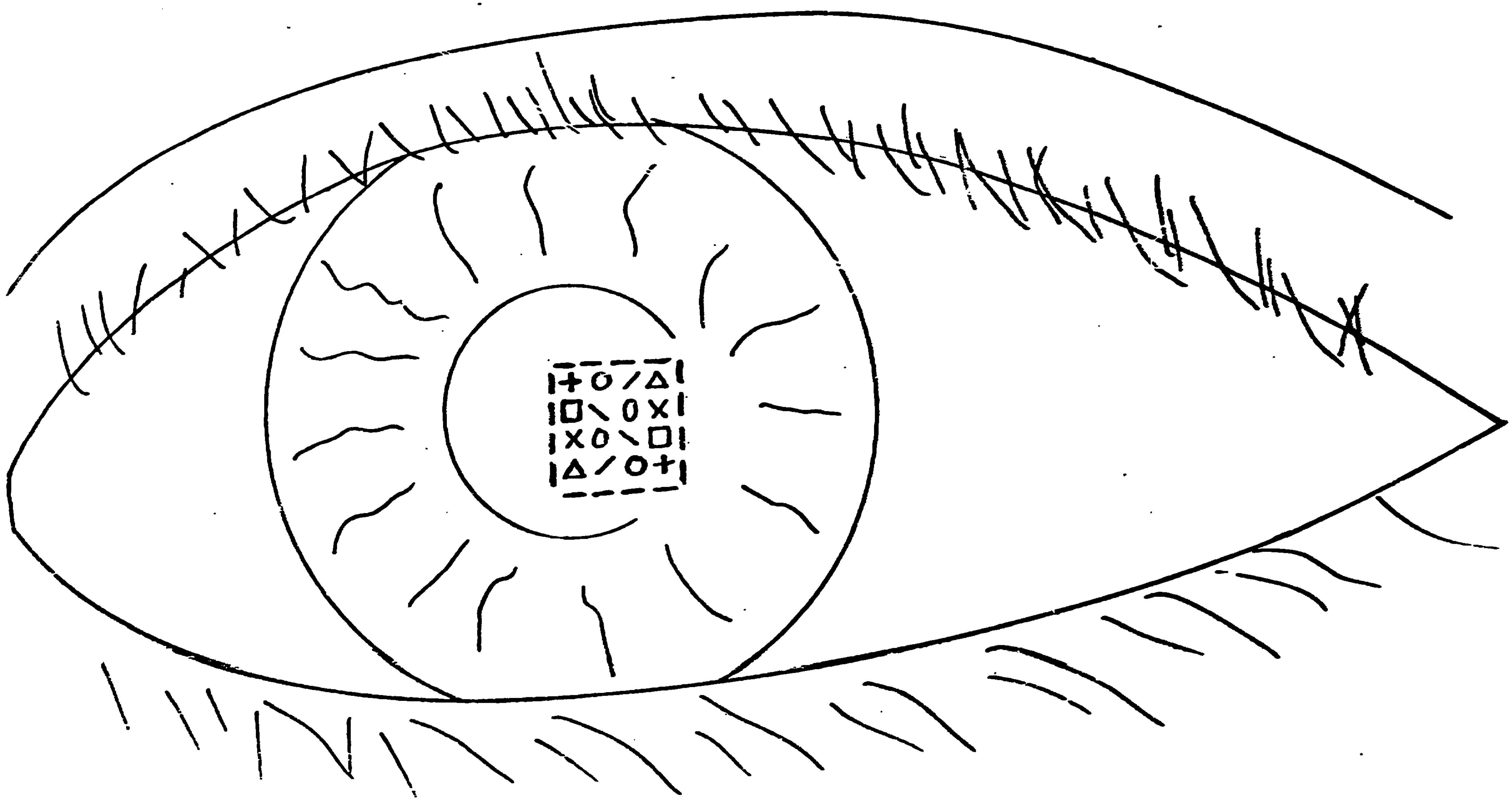


Figure 2 Drawing from photograph taken from Mackworth's Reflection Eye Movement Camera. Subject is Fixating a Square in the Visual Field.

The data were reduced by slow-motion 16mm picture photography from the television screen of the video tape playback system to prepare it for frame analysis. Fixation time was based upon an analysis of materials filmed at five frames per second. Fixation time is defined in this experiment by this condition of data reduction, and various statistics for data analysis were derived from this basic quantification. The basic categories of enumeration were derived as follows: the four quadrants in the visual display area, a center area equivalent to a quadrant which includes the central one-fourth of each of the four quadrants, fixation occurring outside of the visual field and frames not readable due to blinking of the eye lid.

The visual information was presented by a Kodak carousel projector programmed with 80 slides. The slide changing time was based upon a stereo tape recorder cue track and was not dependent upon the timing mechanism of the carousel projector. The cue track that was used was derived from 16mm magnetic film edited to provide a precise synchronous excitation pulse through to the projector every five seconds. Accuracy in slide change intervals was better than $\pm .02$ seconds over the five-second period. The slide change excitation pulse also advanced a counter that was displayed in the visual field of the recording television camera, thus accurately defining on the video tape the visual presentation then available for the subject. An additional cue was made possible by the recording on the video tape of the visual display's reflection from the cornea surface of the subject's eye. Only gross information is available from this cue, however, due to the low resolution of the television system, but it did provide sufficient information to identify the particular visual presentation.

The experimental apparatus consisted then of a slide projector, which presented through a rear screen and a mirror the visual aspect of the experimental program. The subject sat at an opening in the apparatus and looked on a one-way viewing glass at the reflection of the rear screen. The television camera photographed the pupil of the right eye through this one-way glass. Neither the camera and its associated apparatus nor the microphone hidden inside the opening in the immediate proximity of the subject's mouth was visible to the subject. (See Figure 3)

The audio presentation was provided by two speakers mounted on either side of the subject's head within two inches of the ears. The accoustical arrangement was similar to the open type telephone booth. This construction and the proximity of the speakers to the ears tended to mask any extraneous noises in the greater accoustical environment.

One difficulty in data reduction from the video tape was created by the extremely dark brown iris coloration of some of the subjects. This made it difficult to differentiate photographically from the original video tape recording. In order clearly to define the iris/pupil interface, a special video intensifier was developed. This, in effect, greatly increased the contrast of the television play-back system based upon an adjustable location on the gray scale gradiant slope of the video information. In other words, an extremely small difference in gray scale could be exaggerated to a resultant black or white display. The locus of this exaggeration was created by visual examination of the TV screen for each subject in the experiment.

All electronics equipment was created from integrated circuits and proved completely reliable within the experimental situation. The

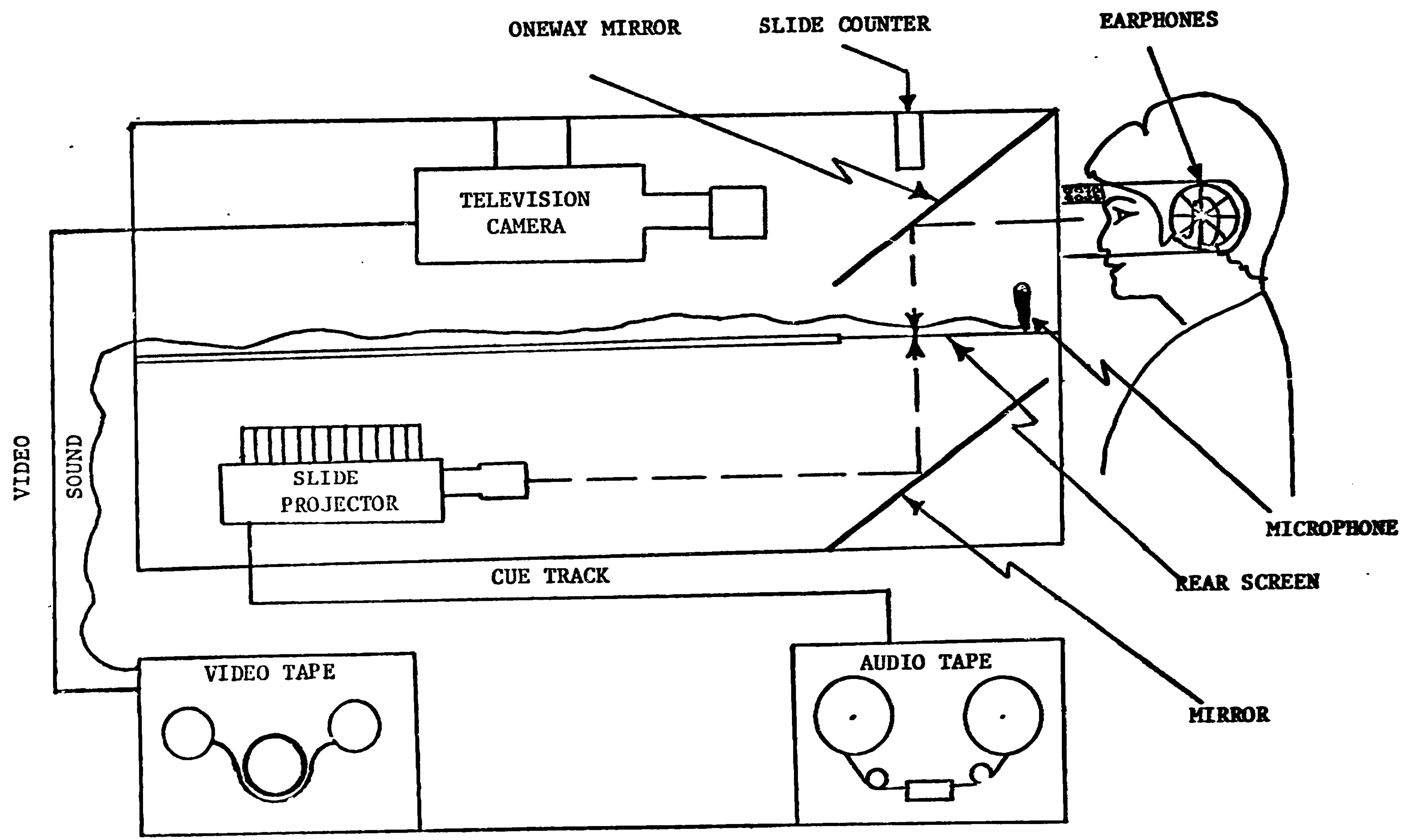


Figure 3 Diagram of the Apparatus as Developed and Used in the Present Experiment.

television camera and the 1/2" video tape recorder were both manufactured by Concord. Each procedure was seven minutes long. Four subjects were recorded on each tape. The reduction to film was accomplished with the use of an Arroflex model S 16mm motion picture camera using Kodak Tri-X negative motion picture film. In order to provide utmost quality, a special film development procedure was used in a motion picture processor developed by the author for use in this experiment. Development was by Diafine, which tolerated a wide range of exposure and which provided maximum contrast under the data reduction conditions. Analysis of data from the motion picture film was by means of a modified Kodak analyst projector. The modification was by B&W and provided for single-frame operation. Each frame was in turn displayed on a large rear screen (tabletop), and the location of the fixation area determined by the author. In all instances, the author did the analysis, relating verbally the location to an assistant who recorded it with paper and pencil. The recording was accomplished on an IBM multiple scoring sheet and computer cards were punched from the sheet. Data reduction, data recording, and data translation took two days to be accomplished. Several checks of rater accuracy were made and the rater was consistent in each check. The visual area of display of each frame was 10" x 12" making accurate judgement relatively simple.

Subjects. A total of 40 children from grades eight through 12 served as subjects in the experiment. Of these, 22 were white, 10 were black, four were Oriental and four were Mexican-American. The subjects were drawn from a roster of students for the Stanford University Summer Microteaching Clinic held during the summer of 1968.

The roster was developed by the clinic to provide a 'representative' student population for practice teaching purposes. Random sampling was not applied in the selection of these students, so generalization to a defined population is not clear. Randomization of subjects to treatment within the experiment was used.

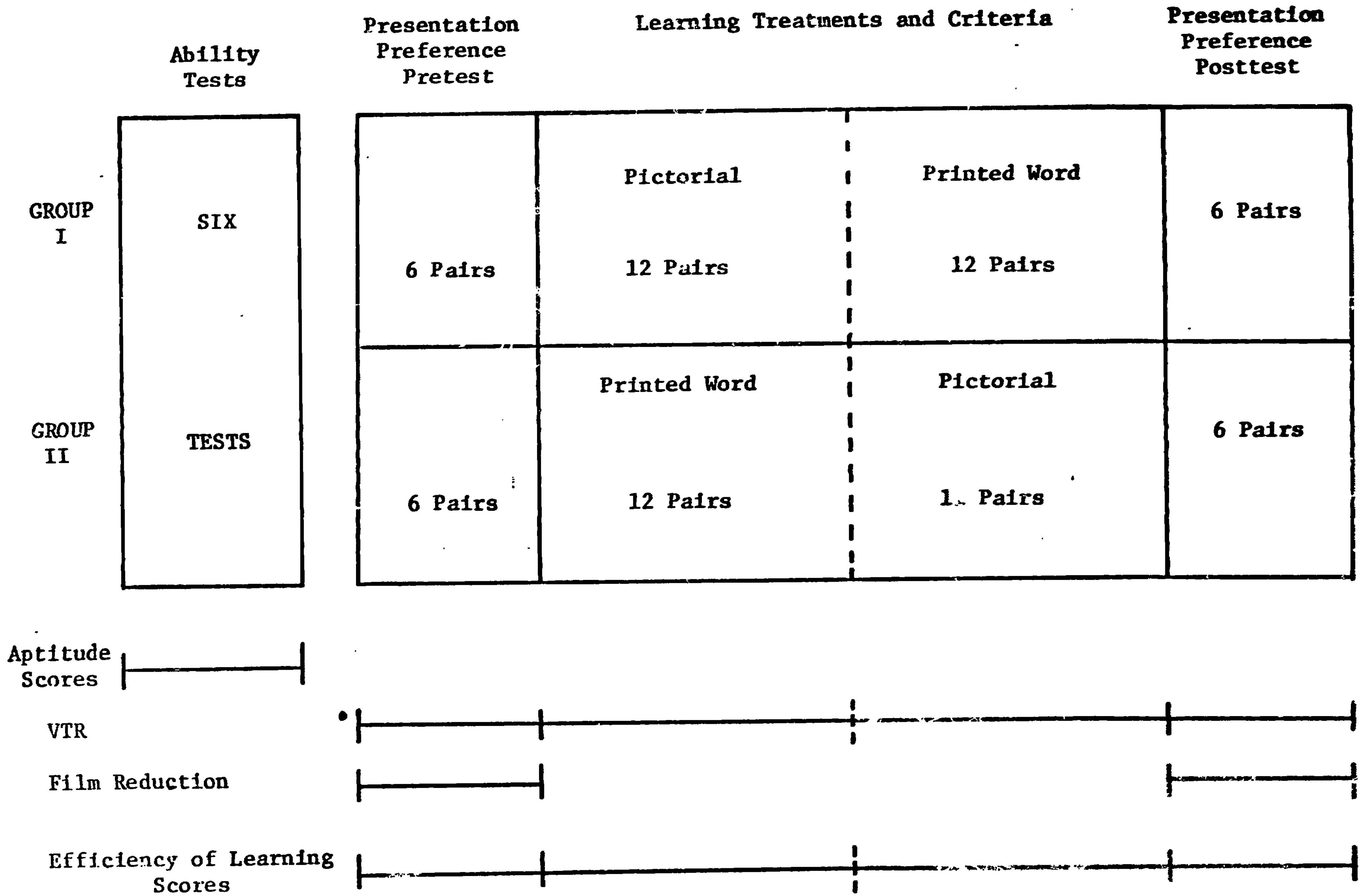
Procedure. During the experimental phase, treatments were counter-balanced to check possible presentation order effects. The criterion tests for efficiency of learning with visual print representation and visual pictorial representation were administered within the experimental procedure itself. Criterion responses were given orally and were recorded on a video tape recorder simultaneously with the video recording of eye movement information. The original video tapes are available for analysis.

Each subject was presented with a paired-associate learning situation using materials taken directly from those supplied by Rohwer from his Experiment VIII on sentence elaboration with verbal and pictorial materials. All subjects learned a list of 24 object-word pairs. The original Rohwer materials used 35mm slides for the printed representation and 16mm motion picture film for the pictorial representation. For the present experiment, 35mm slides were created directly from Rohwer's 16mm film frames for the pictorial representation.

The presentation of the experiment was fully automated and lasted seven minutes.

Experimental Design. The experimental design is displayed in Figure 4. The learning treatments and criteria were presented on the screen in front of the subject in two groups of 12 sets of paired visual stimuli each. One group provided pictorial representation and the other presented print representation. Order of presentation was counterbalanced

Figure 4 Experimental Design



in nested presentations. For example, visual stimuli would be

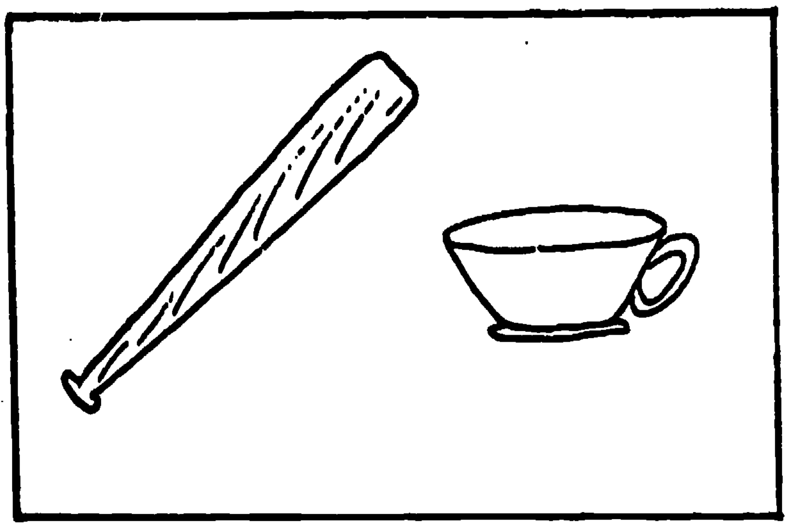


Figure 5:

Paired-Associate Learning

Visual Frame: Pictorial

"The bat strikes the cup."

Figure 6:

Paired-Associate Learning

Visual Frame: Printed Word

accompanied by the sound track ("The bat strikes the cup.") In the pictorial representation condition the subject viewed a picture of the objects (see Figure 5), and in the verbal condition, a printed sentence identifying the objects. (See Figure 6.) At the end of the learning trial, the subject was given a randomized test trial and his oral responses were recorded.

The pretest and posttest evaluated by means of an eye camera the subject's use of his eyes in scanning two simultaneously presented paired-associate visual stimuli, one verbal and the other pictorial. Presumably some subjects would prefer to look at pictures of objects while others would choose to look at the printed name of the object.

(See Figure 7.)

Evaluation of Eye Fixation Preference. In order to rate the fixation variables, a precise time sampling of the recorded process of eye movement was devised. This was accomplished by obtaining five 16mm motion picture frames per second. Since each slide was presented for five seconds, a total of 25 frames per slide was available for rating.

Variables. There were four kinds of variables involved in the experiment made up of ability, demographic, eye movement fixation, and associative learning measures.

Ability Measures. The abilities chosen from the Kit of Reference Tests (French et. al., 1963) were as follows:

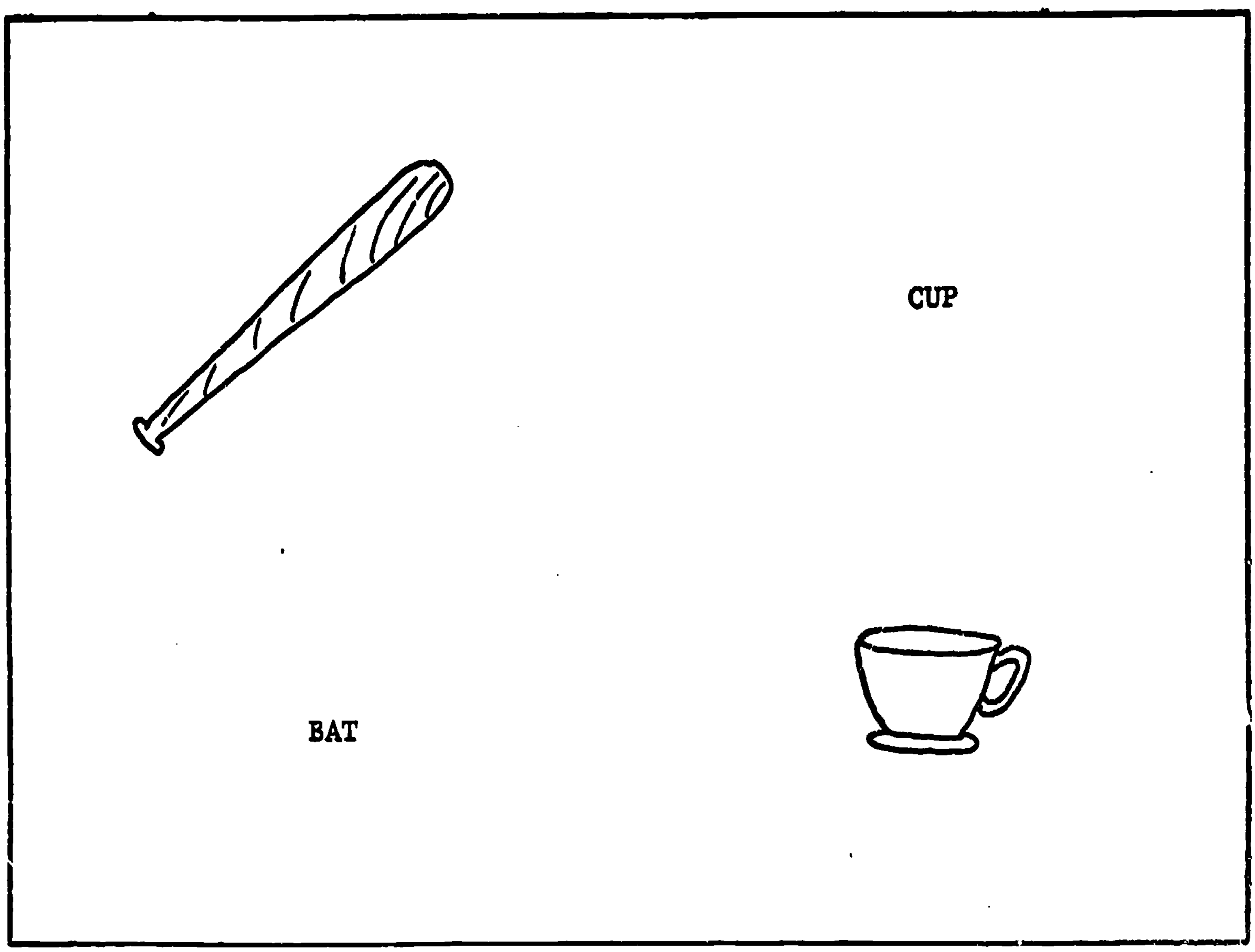
1. S-2, Cube Comparisons Test.
2. P-3, Identical Pictures Test.
3. Ss-1, Maze Tracing Speed Test.
4. R-4, Necessary Arithmetic Operations.
5. Vz-3, Surface Development Test.
6. V-3, Wide Range Vocabulary Test.

Each of the above tests are made up of two parts. For the purposes of this experiment, each part was considered separately. Thus, there were a total of twelve ability measures derived from the Kit of Reference Tests for Cognitive Factors.

Demographic Measures. There were four natural measures included in this set of variables. They were: Race (white vs. non-white); Age; Grade; and Sex.

Eye Movement Fixation Measures. There were seventeen measures derived from the rating of the still frames of the film reduction

Figure 7 Visual Frame Construction Used in Both Pretest and Posttest Presentations



from the video tape recordings of the subjects' eye movements during the pretest and posttest of the experiment. Since there were six slides in each of these two tests, and each slide was on for five seconds, and five frames were photographed during each second, a total of 150 frames were obtained for each test phase per subject with a grand total of rated frames of 300 per subject for the whole experiment. Given forty subjects, a total of 12,000 fixation ratings were accomplished.

The eye movement variables evaluated in this experiment from the rated frames of the pretest were referenced to quadrants of the displayed visuals of the pretest and posttest as follows:

1. Pictorial Stimulus Fixation Time.
2. Printed Word Stimulus Fixation Time.
3. Center Quadrant Fixation Time.
4. Printed Word Response Fixation Time.
5. Pictorial Response Fixation Time.
6. Eye Blink Time.
7. Off-Display Fixation Time.
8. Total Pictorial Fixation Time.
9. Total Printed Word Fixation Time.

The following seven measures sum for each subject the total number of fixations on the identified quadrant that were followed by another fixation on the same quadrant.

10. Remain on Pictorial Stimulus Fixation Time.
11. Remain on Printed Word Stimulus Fixation Time.
12. Remain on Center Quadrant Fixation Time.
13. Remain on Printed Word Response Fixation Time.

14. Remain on Pictorial Response Fixation Time.

15. Total Quadrant Change Fixation Times. This measure gives for each subject the total number of frames where the fixation location was different from the preceding frame.

16. Remain in Eye Blink Condition.

17. Remain in Off-Display Condition.

Associative Learning Measures

1. Pretest Efficiency of Learning Score. The number of pair-associates correctly supplied in the pretest of the six possible.

2, 3. Criterion Measures. There were two dependent variables involved in the present experiment. The first was the associative learning score for the pictorial representation criterion test. The second was the associative learning score for the printed word representation criterion test. The ten posttest measures were obtained as in the pretest.

Summary of Main Variables

		Part			Part
1.	Cube Rotation	1	9.	Surface Development	1
2.	Cube Rotation	2	10.	Surface Development	2
3.	Identical Picture	1	11.	Wide Range Vocabulary	1
4.	Identical Picture	2	12.	Wide Range Vocabulary	2
5.	Maze Tracing	1	13.	White/Non-white	
6.	Maze Tracing	2	14.	Age	
7.	Necessary Arithmetic	1	15.	Grade	
8.	Necessary Arithmetic	2	16.	Sex	

Pretest

17. Pictorial Stimulus Fixation Time
18. Printed Word Stimulus Fixation Time
19. Center Quadrant Fixation Time
20. Printed Word Response Fixation Time
21. Pictorial Response Fixation Time
22. Eye Blink Time
23. Off-Display Fixation Time
24. Total Pictorial Fixation Time
25. Total Printed Word Fixation Time
26. Remain on Pictorial Stimulus Fixation Time
27. Remain on Printed Word Stimulus Fixation Time
28. Remain on Center Quadrant Fixation Time
29. Remain on Printed Word Response Fixation Time
30. Remain on Pictorial Response Fixation Time
31. Remain in Eye Blink Condition
32. Remain in Off-Display Condition
33. Total Quadrant Change Fixation Time
34. Pretest Efficiency of Learning Score

Criteria Tests

35. Dependent Variable: Pictorial Efficiency of Learning Score
36. Dependent Variable: Printed Word Efficiency of Learning Score

Posttest

37. Pictorial Stimulus Fixation Time
38. Printed Word Stimulus Fixation Time
39. Center Quadrant Fixation Time
40. Printed Word Response Fixation Time
41. Pictorial Response Fixation Time
42. Eye Blink Time
43. Off-Display Fixation Time
44. Total Pictorial Fixation Time
45. Total Printed Word Fixation Time
46. Posttest Efficiency of Learning Score

RESULTS

Major Hypothesis I

Effects were examined by a two-way analysis of variance with repeated measures using presentation order and mode as the two independent variables. Table I presents the analysis of variance summary using efficiency of learning as criterion. The analysis showed no significant main effect for order of presentation but did show a significant main effect for picture vs. print presentations. The interaction of order with presentation mode was also significant ($p < .05$). Since the main effect for order of presentation was not significant, and due to the very sensitive statistical test used to assess this effect, this interaction is seen as having little importance and will be ignored in subsequent analyses.

Major Hypothesis II

This hypothesis states that preference expressed by eye fixation variables for several visual representation modes were related to efficiency of learning using those modes. Table 2 presents the correlation matrix simplified by showing the significant ($p < .05$) and near significant ($p < .10$) correlations only and giving the overall means and standard deviations for the major variables developed and used in the present experiment.

The relationships were clear and in the predicted direction, but only parts were statistically significant. The negative relations predicted between each stimulus fixation count, Pictorial Stimulus Fixation and Printed Word Stimulus Fixation (V17 and 18) and success on the opposite treatments were significant. The predicted positive relations were significant for one and approached significance for the

Table 1 Analysis of Variance Summary Using Efficiency of Learning as Criteria for Order of Presentation Effects (A) by Pictorial vs. Printed Word Presentation Mode Success (B). n = 38

		df	Mean Square	F Ratio
Between Subjects				
A	Order of Presentation	1	10.32	1.29
S/A	Subjects Within Groups	36	7.97	
Within Subjects				
B	Pictorial vs. Printed Word	1	320.21	114.36**
AB	Interaction	1	17.05	6.08*
SA/B	Subjects	36	2.80	

* = p .05
** = p .01

Cell Means and (Standard Deviations)

		B: Pictorial	B: Printed Word
A	1	9.26 (1.59)	4.21 (2.44)
	2	9.05 (1.90)	5.89 (2.90)

	French Cognitive Ability Tests												Personal Data									Eye Fixation Variables												Pre-test Dep. V's.				
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	MEAN	S.D.
1 CUB 1		64°	45°	53°	44°	49°			64°	69°	48°	41°																						36°	36°	41°	11.3	3.7
2 CUB 2			45°	37°	30°	37°	35°	47°	60°	58°	43°																							32°	38°	22	12.4	3.3
3 IDEN 1				76°	36°	45°		30°	56°	54°	39°	33°							-30°				33°					-32°				38°		30°	16	18	33.2	7.2
4 IDEN 2					41°	43°		43°	64°	63°	53°	51°							-30°																27	24	35.8	8.6
5 MAZE 1						85°		30°	56°	47°	31°		31°								30°				-33°										34°	-09	10.6	3.7
6 MAZE 2							32°	33°	60°	48°	33°																								29	-11	13.4	3.7
7 ARIT 1								71°	49°	33°	40°	37°																					38°	35°	29	07	6.9	3.3
8 ARIT 2									60°	55°	63°	49°																					41°	50°	41°	18	5.8	3.7
9 SURF 1										86°	74°	64°																				31°	36°	65°	50°	33°	15.1	6.5
10 SURF 2											64°	67°																				33°		51°	49°	45°	16.6	9.0
11 VOCA 1												81°	37°		30°													30°	-36°				37°	51°	40°	33°	9.0	4.2
12 VOCA 2													35°		40°																		31°	40°	36°	34°	7.8	4.0
13 RACE																				-35°		32°			-38°				-38°					45°	27	18	0.6	0.5
14 AGE															82°																				-24	-37°	14.6	1.1
15 GRADE																																			-14	-19	9.8	1.1
16 SEX																															-32°				-08	-17	1.4	0.5
17 PS F																		-56°		-48°				84°	-73°	95°	-54°		-52°						28	-35°	32.5	10.6
18 PWS F																								-54°	60°	-54°	95°								-30°	15	32.5	9.6
19 CTR F																				-34°					-33°			95°	-34°						08	05	7.9	3.4
20 PWR F																					-61°			-69°	78°	-50°		-32°	96°	-56°				-48°	-07	11	37.3	12.2
21 PR F																								72°	-64°	32°			-54°	94°					09	10	33.9	8.3
22 EB																														-30°	89°		30°		-02	-04	4.8	5.3
23 OD F																																99°			-02	07	1.0	3.0
24 TP F																									-88°	86°	-48°		-68°	72°					25	-20	64.4	14.8
25 TPMF																										-73°	57°	-36°	88°	-60°				-38°	-24	18	69.8	15.4
26 RPS F																											-46°		-47°	44°			-33°		28	-26	19.6	9.4
27 RPWS F																																			-31°	15	19.8	7.9
28 RCTR F																													-34°				38°		11	12	1.4	2.3
29 RPWR F																														-46°				-47°	-08	18	23.6	10.6
30 RPR F																																	-49°		16	17	21.8	7.6
31 REB																																			-13	02	1.3	2.7
32 ROD F																																			08	08	0.6	2.2
33 TQC F																																		31°	-05	-20	56.2	10.9
34 PRETEST																																			37°	38°	4.1	1.4
35 DV:PICT																																				47°	9.2	1.8
36 DV:PRINT																																					5.6	2.8

Table 2 Correlation Matrix with Means and Standard Deviations for Significant and Near Significant Predictor and Criteria Variables.

other. Correlations for the response terms were near zero. Taken together, these findings suggest the predictive value of eye movement data for use in the study of pictorial vs. printed word representation in associative learning situations.

Although Hypothesis II dealt with only eye fixation variables, the regression slopes obtained between the criterion measures and each of the predictor variables under each treatment were tested for the extent to which they differed. Table 3 presents tests of parallelism for all variables of the experiment.

Both variables that indicated significant negative prediction of criteria under print treatments, Pictorial Stimulus Fixation (V17) $p < .01$, and Remain on Pictorial Stimulus (V26) $p < .05$, were related artifactually; they were derived statistically from the same information. Figure 8 displays the regression slopes of these two variables with the two criterion treatments.

These results support the hypothesis of interaction between the eye fixation strategies used and performance on the criterion measure where picture and print representations are offered as alternative aids to audio-visual instructional materials.

Major Hypothesis III

This hypothesis states that prediction of learning success would be enhanced by the addition of eye movement variables to more conventional paper and pencil ability tests.

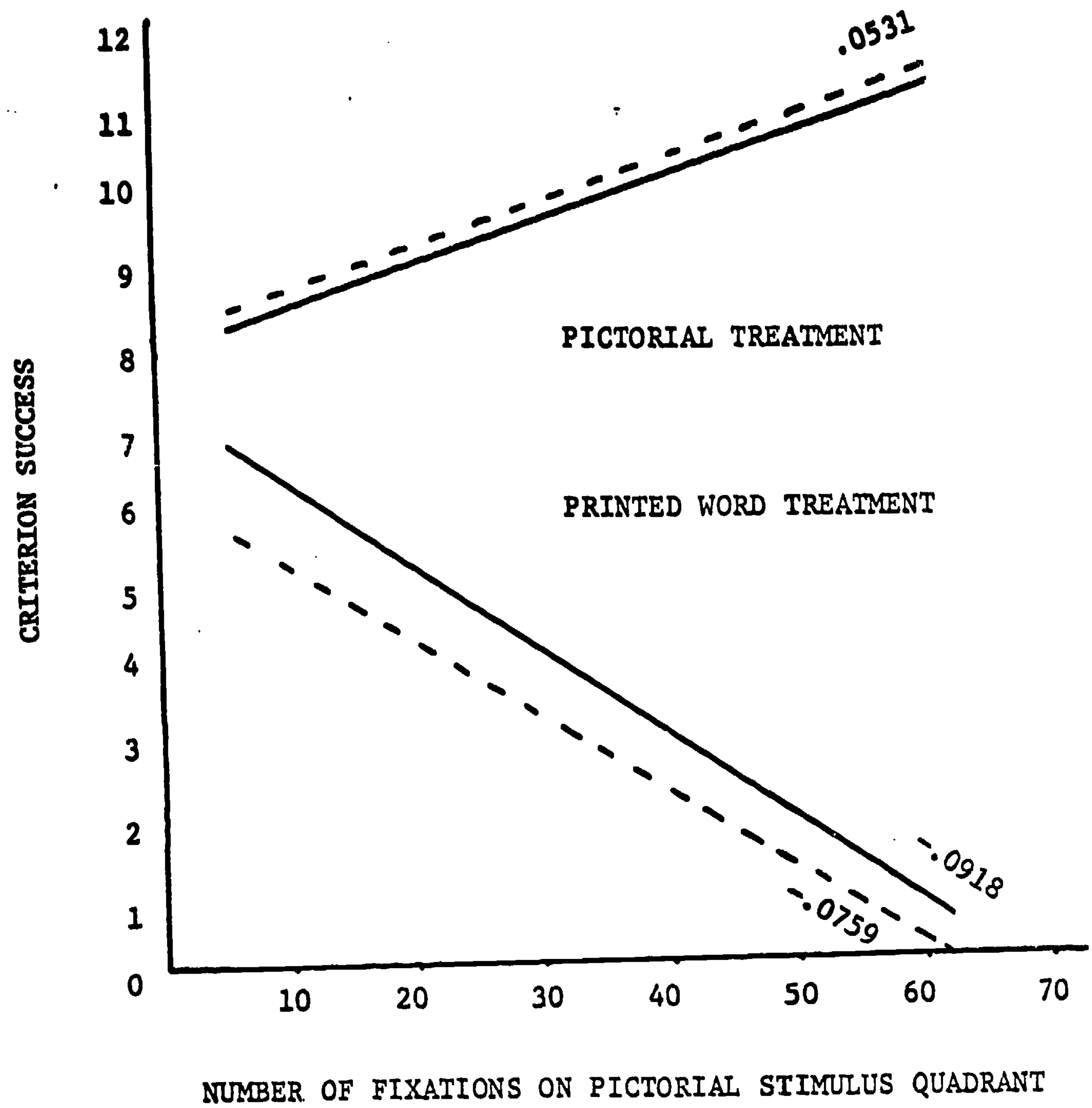
Multiple Regression Analysis. Two kinds of multiple regression analyses were used to examine the relationship between the predictor variables and the two criteria. The first analysis used a Step-wise Regression Analysis (Biomedical program, O2R), and MUREG, a program derived from the Biomedical program that provides standardized Beta weights for the regression analyses. The second analysis used a

Table 3 Test of Parallelism of Regression Results between the Main Variables and the Two Learning Criterion Measures

	Ability Measures		F Ratio	Pictorial beta	Printed Word beta
1.	Cube Rotation	1	0.01	.17	.30
2.	"	2	0.00	.19	.20
3.	Identical Pictures	1	0.17	.04	.07
4.	"	2	0.13	.06	.08
5.	Maze Tracing Span	1	2.56	.16	-.06
6.	"	2	2.37	.14	-.08
7.	Necessary Arithmetic Operations	1	0.36	.15	.06
8.	"	2	0.16	.19	.14
9.	Surface Development	1	0.01	.14	.14
10.	"	2	0.11	.10	.14
11.	Wide Range Vocabulary	1	0.24	.17	.23
12.	"	2	0.35	.16	.23
	Personal Data Measures				
13.	White/Non-White		0.00	1.00	1.28
14.	Age		1.47	-.40	-.97
15.	Grade		0.29	-.22	-.48
16.	Sex		0.43	-.27	-.95
	Static Eye Fixation Measures				
17.	Pictorial Stimulus		8.44**	.05	-.19
18.	Printed Word Stimulus		3.31	-.06	.04
19.	Center Quadrant		0.00	.04	.04
20.	Printed Word Response		0.63	-.01	.02
21.	Pictorial Response		0.05	.02	.03
22.	Eye Blink		0.02	-.01	-.02
23.	Off-Display		0.10	-.01	.06
24.	Total Pictorial		3.55	.03	-.04
25.	Total Printed Word		3.14	-.03	.03
	Dynamic Eye Fixation Measures				
26.	Remain on Pictorial Stimulus		5.58*	.05	-.08
27.	Remain on Printed Word Stimulus		3.55	-.07	.06
28.	Remain on Center Quadrant		0.06	.08	.14
29.	Remain on Printed Word Response		1.39	-.01	.05
30.	Remain on Pictorial Response		0.11	.04	.06
31.	Remain in Eye Blink Condition		0.30	-.08	.02
32.	Remain in Off-Display Condition		0.16	.00	.09
33.	Total Quadrant Changes		0.82	-.01	-.05
34.	Pretest Learning Score		0.62	.48	.77

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

Figure 8 Significant Pictorial Stimulus Fixation Regression Slopes with Pictorial and Printed Word Criterion Treatments.



——— Pretest Pictorial Stimulus Fixation, (V17). Slope difference F = p $<$ .01

- - - Pretest Stay on Pictorial Stimulus, (V26). Slope difference F = p $<$ .05

Table 4 Stepwise Regression Prediction of Pictorial Criterion from Population of All Major Predictor Variables.

Pictorial Criterion					
Step Number	Variable Number	R SQ.	RSQ Increase	F in/out	Label of Variable
1.	9	.25	.25	12.44**	Surface Development 1
2.	26	.38	.13	7.64**	Remain on Pictorial Stimulus
3.	29	.45	.07	4.62*	Remain on Print Response
4.	14	.50	.06	3.90	Age
5.	28	.55	.04	3.37	Remain on Center
6.	8	.57	.03	2.05	Arithmetic Operation 2
7.	6	.60	.02	1.92	Maze Tracing 2
8.	10	.61	.01	0.99	Surface Development 2

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

Table 5 Stepwise Regression Prediction of Printed Word Criterion from Population of all Major Predictor Variables.

Printed Word Criterion					
Step Number	Variable Number	R SQ.	RSQ Increase	F in/out	Label of Variable
1.	10	.20	.20	9.53**	Surface Development 2
2.	14	.34	.14	7.73**	Age
3.	6	.53	.19	14.62**	Maze Tracing 2
4.	33	.58	.06	4.64*	Quadrant Movements
5.	11	.66	.07	7.46**	Wide Range Vocabulary 1
6.	17	.71	.05	5.28*	Pictorial Stimulus
7.	27	.73	.02	2.28	Remain on Printed Word Stim.
8.	34	.75	.02	2.99	Pretest Success

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

routine test for parallelism of regression.

The results of the step-wise regression analysis for each of the two criterion variables are displayed in Tables 4 and 5.

Thus, Hypothesis III is confirmed. As can be seen in the tables, the contribution of the eye movement variables was of major importance in the regression formulas, especially the pictorial and printed word stimulus and the printed word response indices. When taken by themselves, the eye movement variables produced RSQ's of .20 and .34, respectively, for pictorial and printed word criterion. However, when combined with the ability tests, the explanation of variance accounted for reached near .60 for the pictorial and .70 for the printed word criteria.

Additional Analysis

Table 6 presents the fixation preferences for the subjects under different conditions of representation made for stimulus and response quadrant viewing in the pretest and posttest. In the main, 21 subjects did not change their stimulus-response representation mode strategy of fixating between the pretest and posttest. Of the 19 remaining, 12 moved to more posttest pictorial fixating and seven moved to more printed word fixating.

A Chi-square analysis of the differences between the expected and obtained frequencies of subject fixations for the whole matrix resulted in a significant difference ($p < .001$).

Eye Movement and Learning Consistency. A comparison of the pretest and posttest eye fixation data provided an index of consistency. (See Figure 9.) In terms of the range of the scale involved and the potential changes possible within that scale, the finding of only a few just significant fixation changes and no large changes reinforces

Table 6 Subject Preferences Expressed by the Larger of the Two Representation Mode Sums in Pretest and Posttest Stimulus and Response Fixation Conditions.

Posttest	Pretest: Pictorial Stimulus, Pictorial Response	Pretest: Printed Word Stimulus, Printed Word Response	Pretest: Pictorial Stimulus, Printed Word Response	Pretest: Printed Word Stimulus, Pictorial Response
Pictorial Stimulus, Pictorial Response	9	1	1	6
Printed Word Stimulus, Printed Word Response		6	4	3
Pictorial Stimulus, Printed Word Response		4	3	
Printed Word Stimulus, Pictorial Response				3

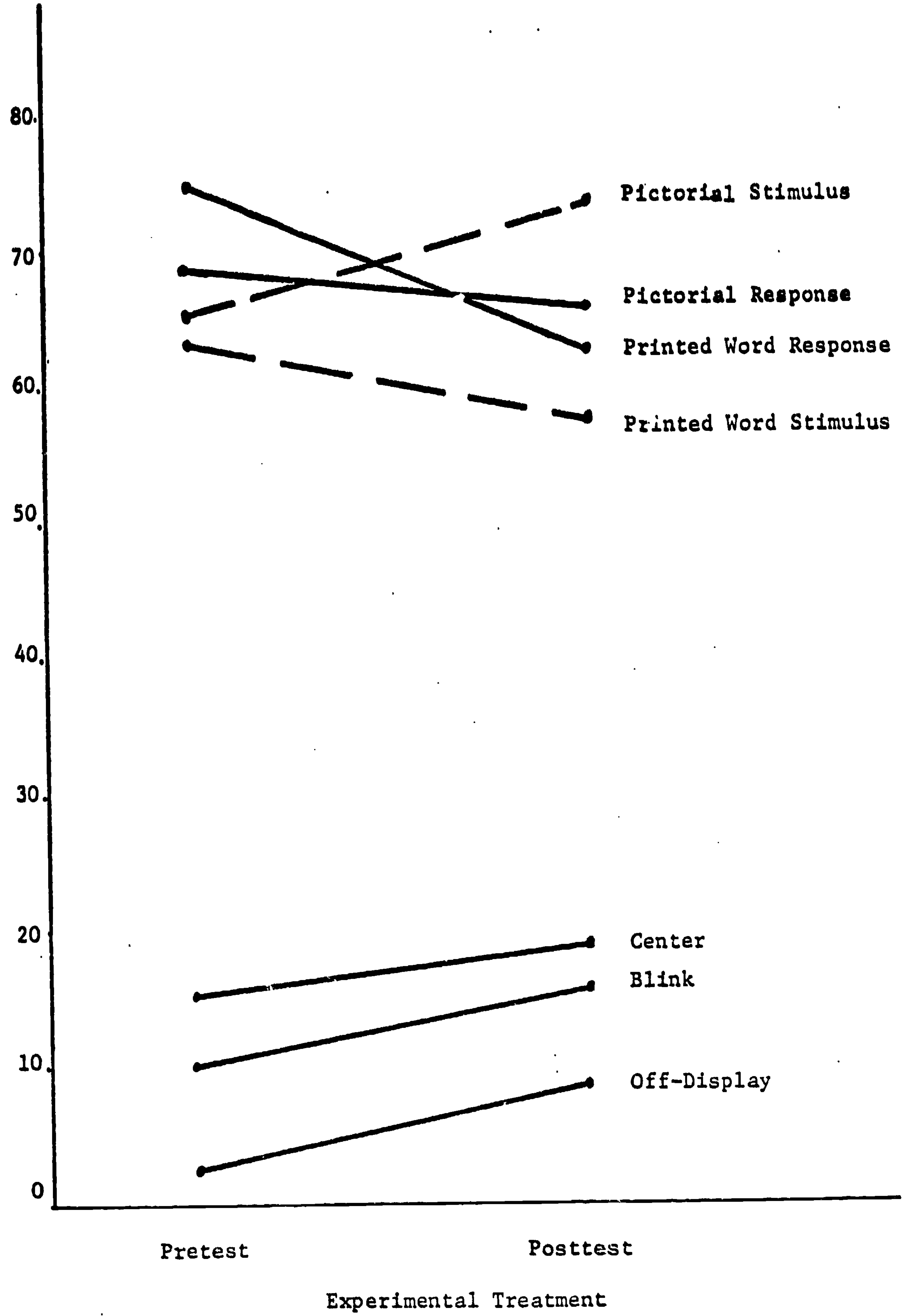


Figure 9 Fixation Change Patterns: Pretest to Posttest.

the view of the relative consistency of the eye fixation phenomena and renders them worthy of continued interest.

DISCUSSION AND CONCLUSIONS

For Hypothesis I, the analysis showed no significant main effect for order of presentation but did show a significant main effect for pictorial vs. printed word presentations and the interaction with presentation mode. Thus, Rohwer's argument that pictorial supported audio-visual associative learning is superior to printed word supported audio-visual associative learning was confirmed.

In fact, this was a much larger difference than previously reported. (Rohwer, 1967) It should be noted that in the present study subjects served as their own controls. It would appear that the additional control and/or change of age of the subjects could be considered plausible reason(s) for the greater difference found here relative to Rohwer's data.

For Hypothesis II, the relationships were clear and in the predicted direction, but only parts were statistically significant. Correlations for the response terms were near zero. The tests for parallelism supported the hypothesis of interaction between eye fixation strategies used and pictorial vs. printed word presentation modes using learning performance as criterion. Taken together, these findings suggest the predictive value of eye movement data for use in the study of pictorial vs. printed word presentation modes as differential educational treatments.

For Hypothesis III, 34 predictor variables were examined in relation to the two criterion variables using zero order correlation,

multiple step-wise regression, and Chi-square analysis. In general, the following were involved significantly in the prediction: four out of six cognitive ability tests - Surface Development, Arithmetic Operation, Maze Tracing Span, and Wide Range Vocabulary; one demographic variable - Age; six eye fixation variables - Pictorial Stimulus Fixation, Remain on Pictorial Stimulus, Remain on Printed Word Stimulus, Remain on Printed Word Response, Remain on Center, and Quadrant Change Movements; and Success on the Pretest.

These analyses support the acceptance of Hypothesis III. The eye movement variables showed little correlation with either the ability or demographic variables, yet their inclusion in the multiple regression prediction greatly increased the amount of variance accounted for. Multiple regression prediction explained 60% of pictorial criterion success and 73% of printed word criterion success. The Chi-square analysis showed a change from early response fixating strategy to later equal fixating of stimulus and response and also a general trend of strategy change in the direction of greater pictorial fixation.

In terms of the demographic variables, little contribution to prediction was found except for the negative correlation of age with the printed word criterion. No explanation for this finding is available. The expected correlation with grade was obtained. Other variables related to social class need to be evaluated in investigation of cultural possibilities of eye movement in general (Segall, 1966) as well as the difference in printed word response fixating found among the races. With respect to race, whites did significantly better in the pretest; they showed less printed word fixating, especially on printed word responses; and more blinking than did non-whites. Boys blinked more

than girls ($p < .05$).

The high intercorrelations among the cognitive ability tests used interfered with interpretation. Of all of the ability tests used in this study, the Maze Tracing, part 2, presented the only suggestion of differentiation, almost significantly positive ($p < .06$) with the pictorial and mildly negative with the printed word criterion.

In general then, the conventional ability tests are hypothesized as being indicators that lack differentiating qualities in the area of visual representation selection. Maze Tracing Span does offer the possibility of a base for differentiation development. Future research utilizing other ability tests is suggested to explore for their relationship with associative learning.

The results of this study have confirmed the hypotheses posed at its inception. Pictorial presentation mode provided, on the average, twice the learning facilitation of the printed word presentation mode when used in conjunction with synchronous auditory verbal presentations of associative relations between a series of object-pairs. In fact, one criticism of the present study would be related to the probable ceiling effect encountered in all of the learning scores. That two subjects obtained a totally correct learning score in the pictorial treatment is indicative that the raw score range, and hence the mean difference, is too narrow. Providing more difficult nouns to pair, or a longer list to remember, or a shorter time study-trial exposure time would be a profitable direction for materials development.

Individual Perceptual Patterns. The present experiment demonstrated a significant relationship between stimulus selection and success where visual presentation mode options were available, and

offered confirmation through the use of eye movement analysis of the importance of this concept. The point seems well made, however, that different individuals find different stimulus material make a difference in their effectiveness in dealing with their environment.

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