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ABSTRACT

An analysis of the types of eye movements of subjects viewing motion picture films and telelessons revealed a continuum of movements. Two of the intervals of this continuum (No Observable Movements and Minimovements) were found to be related to intelligence. The factors of age and learning did not correlate with any of the indices. Subjects in the experiment were selected from grades 6, 8, and 11; they were divided into nine cells of six subjects each. Four types of films were selected for the stimulus material and were shown as one nineteen-minute film. An analysis of where the subjects looked, called the density analysis, showed that subjects looked at a few well-defined areas of the screen. Results from the density analysis are suggestive for producers of educational films and telelessons, as various scene variables are influential on where the subjects look. In addition, since differences in viewing patterns occurred between the subgroups of age and IQ, these groups should also be taken into consideration in the stimulus development. Appendices contain forms and tests used in the experiment and experimental data resulting from it. (MF)

FINAL REPORT
Project No. 5-0427
Grant No. OEG-7-45-0430-234

A STUDY OF EYE MOVEMENT IN TELEVISION VIEWING

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Principal Investigator

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with

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Lawrence Light, and Bruce Gansneder
Research Associates

August, 1970

U.S. DEPARTMENT of
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The Ohio State University
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Manfred Knemeyer was indispensable in dealing with the many problems encountered during the course of the project. As stipulated in the original contract, a commercial firm was hired to electronically read out the collected eye-movement data. The technical problems unanticipated by this firm caused a two-year delay in the work of the project. Mr. Knemeyer assisted the firm in overcoming these problems and rewriting the computer program designed to translate the data. He subsequently created programs to analyze these data.

While most of the initial staff did not remain at The Ohio State University throughout the project, they were extremely helpful in the early phases. Egon G. Guba was co-investigator at the outset. Although he took a post at another university, he continued to give us assistance and support throughout the years. In addition, Sybil de Groot was Research Associate on the project for several years. She assisted in the project planning, in data collection, in solving the many problems of data read-out, and in writing sections of the final report. Lawrence Light assisted in the project planning and in test development. These latter two individuals, Ph.D. students in the Department of Psychology at The Ohio State University while participating on the project, have since moved to posts in other places. Their assistance was invaluable.

During the past year, Daniel Tira assisted with the data analysis. He conducted most of the analyses, and assisted in interpreting the data and in writing the final report. The insight that he brought to the project with only a short acquaintance with the data was impressive. In addition, Bruce Gansneder provided expert assistance in the data analysis.

Members of the Research Foundation also assisted the staff in solving the many problems encountered in data read-out. Particularly helpful were Louis Higgs, Robert C. Stephenson, and Raymond Bugno.

Acknowledgement is given also to the Bell and Howell Co. for their generosity in lending the staff a projector for use on the project.

Willavene Wolf

SUMMARY

The objectives of this research were (1) to verify whether a continuum of eye movements exists for subjects viewing motion picture films and telelessons, (2) to determine what effect, if any, stimulus characteristics and the subject characteristics of age and intelligence have on the eye-movement indices, (3) to determine the relationship between subjects' recall of the stimulus and their eye-movement indices, and (4) to determine where the subjects look when the stimulus is presented and whether their viewing pattern is influenced by certain stimulus and subject variables.

Subjects in the sample were selected from grades 6, 8, and 11 of the Columbus, Ohio public schools. They were screened to eliminate individuals who had defective hearing or who failed to meet the requirements for normal, uncorrected vision. The sample consisted of three grade levels with three IQ groups in each level. A total of 54 subjects provided six subjects in each of the nine cells in the initial sample although the sample was later reduced because of technical difficulties. Four types of films were selected for the stimulus material and were combined into one nineteen-minute film. Each scene in the stimulus film was classified on the variables of motion state, complexity, novelty, clarity, number of attention centers, ambiguity of meaning, unity of elements, arousal characteristics and auditory elements. Two tests were constructed to measure the subjects' recall and understanding of the stimulus film. One of the tests measured the subjects' recognition of the visual portion of the stimulus and the other measured the subjects' recall and understanding based upon an integration of the visual and auditory portions of the film combined. IQ scores were obtained by Henmon-Nelson group tests administered in the public schools. Each subject was brought to the experimental laboratory and presented the stimulus film while his eye movements were recorded with a modified Mackworth corneal reflection apparatus. He was then given a post-test. Data were recorded on film during each experimental session and then transcribed from film to computer tape by a film scanner which was under computer control. Statistical techniques used in the study of the eye-movement indices were mainly analysis of variance and multiple regression. Special programs were developed to determine where the subjects look.

The analysis of the types of eye movements revealed a continuum which was divided into four fairly distinct intervals. These intervals were defined as follows: No Observable Movements (0-4.2°/second), Minimovements (4.2-11.4°/second), Small Saccades (11.4-47.4°/second), and Large Saccades (above 47.4°/second). It was found that intelligence is related to the first two types of indices (No Observable Movements and Minimovements) but that age and learning are not related to any of the indices. Certain scene variables, particularly motion state, affect the eye movement indices.

An analysis of where the subjects look, called the density analysis, showed that subjects look at a few well-defined areas of the screen. The objects they view are influenced by certain scene variables. For example, they look at filled spaces rather than unfilled spaces, concentrate on a single object when it is surrounded by a blank space and divide their attention among many objects when they are present unless there is a novel object in the scene. When a novel object is present, they look at that object in preference to the familiar object. Several other aspects of the scene are influential. Also, differences in viewing occur between High IQ and Low IQ groups and High Age and Low Age groups for certain types of scenes.

The findings have implications for researchers as well as producers of educational films and telelessons. One implication is that researchers should not continue to classify eye movements into the dichotomy of fixations and saccades but rather should use a continuum of movements. Further research on the types of eye movements and the function of these eye movements is suggested. Results from the density analysis are suggestive for producers of educational films and telelessons. For example, various scene variables are influential on where the subjects look. These scene variables should be taken into account when a film or telelesson is being developed. In addition, since differences in viewing patterns occur between the subgroups of age and IQ, these groups should also be taken into consideration in the stimulus development. These implications and others are presented in the Discussion Section of the report.

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CHAPTER I

BACKGROUND FOR THE RESEARCH

Dewey has made a useful distinction between a problem and a task. According to him, a task is where the objective is clearly defined and all that is necessary is to find the means to reach the objective. On the other hand, in a problem neither the objective nor the means for reaching it is clearly in view. The present study would have to be classified as research on a problem. The state of the field and technology at the time this research was begun made both the end and the means to obtain it unclear. As a result, the problem as stated in the proposal has changed over the course of the research. Technical equipment difficulties caused numerous delays in the project as well as a few changes in the questions proposed for analysis. During these delays, experience of the staff as well as new research findings from these and other researchers caused a reconceptualization of the study. Thus, it might be said that over the course of the past few years the research problem evolved, so that by the time of data analysis the questions being considered were slightly different. It is believed by the project staff that the end result is a more realistic statement than the one originally proposed.

THE PROBLEM AS IT WAS STATED IN THE PROPOSAL

Controlled research on fields such as television and motion pictures has been limited by their dynamic and multi-variant nature. For example, if it is desired to compare the effects of two types of scene changes, it may be found that one scene is preceded and followed by subject matter and events of an entirely different order than another type of scene. If one were to control for all of the possible variables including, for example, the components of a scene, the arrangement of the components within a scene, the sequence or ordering of the scene, the perspective or the angle of view, the pace or the frequency of events, and the clarity with which the real world is portrayed, an impossible number of studies would be needed. Such a research effort would be unreasonable in view of the expense involved in motion pictures and television productions. As a result, many of the decisions made by producers about the inclusion and manipulation of various variables have been, of necessity, subjective. The development of these programs is seldom atheoretical since most producers have an assumed, but often unstated, theory. Most of these theories, however, are untested.

In the proposal for this research the state of the art of television was recognized:

> It would seem reasonable to suppose that advances in our knowledge of the device (television), its uses, and its users,

would have kept pace with its rapid development, but this is far from the case. More than a decade of wide-spread and well-financed research activities has yielded little definite information.

Obviously a great deal of basic, descriptive work remains to be done in order to lay the foundation for the more theoretical and hypothetical research which will ultimately follow. Such studies need to be undertaken in a variety of areas beginning with the single perception of the image on the television screen and ranging to complex interpretations hinging upon personal and social factors.

In view of these difficulties, and in order to narrow the variables to some meaningful number, it was decided that perhaps the most fruitful research would be of subjects' eye movements while they viewed educational television or motion pictures.

Eye movements present an unusual opportunity for finding out the reactions of viewers to a visual stimulus. They give information on where the subject is looking, how long he looks at a particular area, how often he looks at particular objects and the types of movements he makes. Carpenter has postulated a theory in which a person's thoughts tend to be shown in certain small muscle movements. His theory suggests that some types of eye movements may be indicators of the subject's immediate response to a visual display. This reaction is different from giving the subject a printed test or asking him in an interview what he has learned from the stimulus. Subjective reporting has been shown to be difficult to use in determining the visual scanning patterns of the individual. The reason for this is that information entering through the visual perceptual system is extensively filtered and processed before reaching the higher centers. This selective mechanism has been demonstrated by Llewellyn-Thomas[15] in studies of people performing tasks such as driving automobiles or landing aircraft. These individuals made many eye movements and fixations which they could not remember and did not realize they had made, but upon which they had based their motor responses.

Quoting from the proposal for the pilot study which preceded this investigation, an analogy with reading was used to show the possible value of eye movement studies.

> It seems reasonable to suppose that studies of eye movements, similar to those conducted in the area of reading, would reveal facts leading to a better understanding of how people view television. An early finding of the reading studies was that eyes do not move in a continuous sweep from left to right across the page when the person is reading regular type, but rather move in a series of quick, short movements and fixation pauses. This fact threw light on the way that people read

and led to a revolutionary change in methods of teaching reading.

Thus the investigators early postulated that eye-movement studies in television might be as fruitful as the eye-movement studies in reading. Although the analysis of the data from the pilot study was not completed when the proposal for this research was written, the preliminary findings from the pilot study appeared to support that assertion.

The data films from the pilot study were of rather poor quality because of technological difficulties; however, the films were informative and suggestive. In that study[14] the films were analyzed by hand on a slow-speed projector and a single-frame film viewer. Viewings of the data by means of the slow-speed projector revealed that there was a marked "clustering" of the eye marker.* It was quite striking how strongly the eye markers were concentrated in a few well-defined areas. A descriptive analysis was made of the objects observed by the subjects and the duration of each observation in order to describe the attention value of the visual stimuli. Such distributions revealed what may operationally be regarded as the center or centers of attention of the scene. The total length of time that the eye marker appeared in each area, as well as the number of times it entered the area, were recorded. Only one educational telelesson (a discussion and demonstration of health habits by a narrator and a fast-paced sequence appended to it) was used as the stimulus material.

In that study when a narrator was present there was a definite tendency for the subjects to focus on his face. The narrator's hands when holding an object and areas discussed by the narrator were also compelling. Since many educational telelessons are based upon a classroom teaching situation with a narrator present, it was decided that it would be important in this study to determine if a narrator in another situation would attract the same attention.

In addition to the findings with regard to the "clustering" of the eye marker, other types of phenomena were observed. When the fast-paced sequence was shown, most subjects attempted to follow the moving objects when they first appeared on the screen. Their initial tendency to look around at the objects was soon replaced by a central fixation; that is, the subjects selected a point near the center of the screen and continued to focus approximately on that point. It appeared that following the highly dynamic scene was such a demanding task that perhaps instead of fixating centrally, the viewer attempted to utilize peripheral vision in keeping abreast of events in the visual field. However, on questioning

*The eye marker is the image of a small spot of light superimposed over the part of the stimulus material at which the subject is looking. It is formed by a light beam reflected from the [illegible] eye of the subject, which moves as the subject's eyes move.

the subjects after the presentation they did not recall the specifics of what was in the visual field. Thus, the behavior appeared not to be a method of coping with, but simply a surrender or withdrawal from, an impossible task.

The term "blooming" was used to characterize another phenomenon in the eye movement reponses of the children. The marker, always sharp and clear after initial calibration, enlarged and diffused temporarily at later times in the viewing. Some of these distortions may be accounted for by helmet slippage caused by excessive head movements, but others were clearly and distinctly the product of movements or translations of the eye back and forth in its orbit. Preliminary observations, including a simulation of the effect by some of the project staff members, indicated at least two possible sources of the phenomenon; i.e., (1) flagging attention and (2) aural-visual conflict as the subject strained to hear what was being said at the expense of seeing the display. The research staff thought it conceivable that this phenomenon, when better understood, might be utilized as an attention index, the application of which is apparent.

Observation of the film records also revealed differences in the viewing patterns of high- and low-intelligence children. The low-intelligence subjects spent a significant proportion of the time off-screen entirely. The eye-movement patterns of high-intelligence subjects appeared to be characterized by a high frequency of movements, sharp and saccadic in nature. The low-intelligence subjects were characterized by slow "sliding" movements rather than saccadic responses.

The objectives stated in the proposal for this research project were based in large part upon these preliminary findings from the pilot study. In general, the objectives were (1) to extend the study to a wider sample of television content and to a wider age sample in order to determine the effects of the stimulus and maturity on eye-movement patterns, and (2) to refine and test the hypotheses suggested by the pilot data, specifically those dealing with intelligence differences, "blooming," "surrender," and such other pattern variables which might still emerge as data analysis of the pilot study was completed.

From these objectives, several questions served as the foci for the study. Representative of these questions were the following: (1) Are there differences in the eye-movement patterns of children of different maturity levels in terms of the objects that attract or distract them and in terms of the "standard" eye-movement measures (e.g., fixation, frequency, inter-fixation distance, and pause duration)? (2) Are there differences in eye-movement responses to varying types of stimulus material, specifically to four different types of films? and (3) Do the "blooming" and "surrender" phenomena observed in the pilot data appear in the new data?

Experience as well as methodological difficulties resulted in a modification of the conceptual framework by the time of data analysis.

The major changes that occurred included a refinement of the eye-movement indices based upon the data analysis from the pilot study, a refinement of the stimuli in terms of variable classification for each scene within a film, and the elimination of the "blooming" phenomenon from consideration in the study.

HOW THE PROBLEM CHANGED

Types of Eye Movements

Shortly after the proposal had been submitted to the United States Office of Education, the project staff completed an additional analysis of the data from the pilot study. The analysis was accomplished by means of a single-frame viewer which required tedious plotting of the distance the subjects' eye markers moved from frame to frame. Only a few scenes could be analyzed on a few subjects because of the time-consuming task of plotting the data. Each scene took many weeks of plotting; however, this part of the data analysis was extremely revealing. In the past, in educational studies of the eye movements of children (usually while they were reading) the results had been reported in terms of fixations and saccades. During a fixation, the eye is stopped on some point of the stimulus field while during a saccade the eyes are moving sharply from point to point. Most of the eye-movement indices reported in these educational studies were geared around these two indices, particularly the fixation; e.g., fixation duration, interfixation distance, saccades, and regressions (saccades backwards). Since the reporting of these indices had been so predominant in the educational and psychological literature, it had been anticipated that only these types of movements would be found in the pilot study. It became evident from the analysis of the data, however, that indices based on the "standard" fixation concept would be inadequate. All of the observable data could not be classified as either fixations or saccades. Rather, an appreciable number of the eye movements fell between these two extremes and represented various intervals along a continuum of movement. The lower extreme of this continuum, analogous to the fixation of other researchers, was termed No Observable Movements (NOMS) since it was assumed that physiological nystagmic-type movements would have been observed had the project staff used even finer instrumentation. At the other extreme of the continuum was the saccade--the same type of movement as was observed by other researchers. Between these two extremes were observed three types of movements. The smallest of these was so small that it was barely perceptible through the use of a single-frame viewer. Had the researchers been satisfied simply to use a slow-speed projector and note where the subjects looked, they would not have observed this movement. It was only after several successive frames had been examined on the single-frame viewer that the analyst could ascertain that one of these movements had occurred. On then going back and rechecking frame by frame, it was evident that the position of the eye marker had observably changed between two successive frames, and that the distance between positions was usually much less than the diameter of the eye marker (approximately 1 degree). These movements were termed Minimovements (MINS) by the project staff. It is important to note that the

MINS were different from nystagmic-type movements in terms of velocity and range. The MINS ranged from a total of 15° of arc to around 30° of arc over several frames. Also, they did not appear to be random in nature and thus probably did not result from instability in the neuromotor system. Rather, they appeared to be related to the stimulus field. It seemed that the Minimovements were used to track outlines or contours of displayed objects. The reliability of the Mackworth camera, however, is about 1° and did not allow a precise statement to that effect. The Minimovements occurred on static as well as dynamic fields.

Another movement was similar to the eye movements reported in studies of visual pursuit of a moving point. As reported in these studies, the eyes move at a rather constant rate with slow velocities of the stimulus, and as the stimulus velocity is increased, the eye movements begin to alternate with saccades until, at high velocities, the eyes follow the stimulus solely by saccades. It was not anticipated that eye movements of the same descriptive nature as the pursuit movements would occur except where objects were moving through the field. However, movements similar to these pursuit movements (termed by the project staff "small slides") did occur at other points on the stimulus field when a moving object was not present. They also occurred when moving stimuli were present, but not as often as might be expected. Similar types of movements, but of a faster velocity and covering a greater distance, were termed "large slides".

In review, the eye movements that were observed in the pilot study, along with their definitions, are presented below. It should be noted here that the diameter of the eye marker was used as the operational unit of extent. This diameter corresponds to about 1° of visual arc.

1. No Observable Movements (NOMS). In operational terms, the position of the eye marker did not observably change between two successive frames. It is assumed that this index includes most of the drifts, small tremors, and physiological nystagmus noted by researchers in such fields as electrical engineering and opthalmology.

2. Minimovements (MINS). The position of the eye marker has observably changed between two successive frames, the distance between positions being less than the diameter of the eye marker and ranging from 15' to 30' of arc.

3. Slides (large and small). The position of the eye marker has observably changed between three successive frames and the distance between the first and second positions, and the second and third positions is each greater than the diameter of the eye marker.

4. Saccades. The position of the eye marker has observably changed between two successive frames, the distance between positions being greater than the diameter of the eye marker, but the distance traversed by the eye marker before and after this event being less than the diameter of the eye marker.

The observation of these various eye movements, several of which were different from the ones reported in studies of reading, still pictures, and motion pictures, prompted the staff to search even further in the literature in other fields. It was found that researchers in fields such as opthalmology, optometry, medical electronics, electrical engineering, and aviation medicine, have also reported eye movements that fall into categories other than fixations and saccades. These categories are variously listed by several scientists including Alpern,[1] Yarbus,[26] Young,[27] and others. One of the most complete categorizations of the types of eye movements has been presented by Laurence Young.[27] A summary of the eye movements he lists which are relevant to this study follows:

1. Nystagmus. A large class of eye movements of an unstable nature. Among the most common types are optokinetic, vestibular, and spontaneous nystagmus. Optokinetic nystagmus occurs when a visual field is moved continuously past an observer. The eyes move with the field and rapidly return to a central position in a movement of a saccadic nature and continue their smooth travel in the direction of the motion of the field. Vestibular nystagmus is a combination of compensatory movements, opposite to the acceleration, and returning saccades. Spontaneous nystagmus may be a sign of oculomotor, vestibular, or nervous disorder.

2. Rolling or torsional movements. Movements of the eye about the line of gaze which are involuntary and compensatory in nature.

3. Miniature movements. Movements of less than 1° in amplitude which are observed during the fixation of a stationary object. Drift, flick, and tremor are associated with these movements.

4. Pursuit movements. Slow tracking movements of 1° to 30° per second with which individuals follow a slowly-moving object. According to Young, these movements cannot be executed in the absence of a moving object.

5. Saccadic or fast eye movements. Little jumps by which the person voluntarily moves his eyes conjugately from one point to another. They may be larger than 50° and are usually 120 to 250 msec in reaction time. The velocity

may be as high as 600° per second for very large excursions and each movement is terminated by rapid deceleration.

These last three categories of Young's list are quite similar to the minimovements, slides, and saccades reported in the pilot study.

Perhaps one of the reasons that most educational researchers who studied eye-movement responses to reading have not reported indices other than fixations and saccades is that subjects reading printed materials may have used no other eye movements. It is more likely, however, that the type of instrumentation used for reading out the data in those studies has caused the researchers to overlook movements that were actually there. The data produced by their instrumentation was often in the form of line graphs where small movements were not so evident. A change of a few seconds of arc in movement might not have been noticed under those circumstances. The apparatus used in the pilot study w the Mackworth Camera which produces the eye marker superimposed over the stimulus material. Thus, even miniature movements of the eye marker could be noticed by looking at the marker in reference to the stimulus underneath it.

One important purpose of the present investigation was to verify the presence of the various eye movements on a much larger sample with a more refined read-out. The read-out system used for precisely noting the position from frame to frame is explained in the Chapter on Procedures. This read-out allowed the staff to observe any movement larger than 3 minutes of arc that took place, and to determine if there were data that fell into specific intervals and if these intervals coincided with the data from Young's study and with the pilot study.

The data from the pilot study were obtained by an observer's "eyeballing" the eye marker from frame to frame and measuring the distance of any movement. The data read-out in the present investigation involved computer read-out on a much finer grid. Thus distance and velocity would be measured with greater precision. Even though the two studies differed in methodology, an approximation of the findings from the first study should be possible.

Eye Movements and Learning

One reason that it appeared relevant to verify the existence of the types of eye movements was the possibility that the movements might be related to the individual's recall of the stimulus presented. Although no relationship was found between the measure of recall of the stimulus material and the eye movements in the first study, the principal investigators reasoned that perhaps the type of test constructed was responsible. The test developed for that study consisted of a true-false instrument based upon an integration of the knowledge the subject gained from both the visual and auditory portions of the film. Subjects' responses to a few items on the post-test for the pilot study indicated that when the visual and auditory portions of the film were contradictory, the subjects tended to remember the visual instead of the auditory portion of the telelesson. Therefore, it is possible that recall of the visual portion of the telelesson should have been measured separately and the relationship of this recall to the subjects' eye movements tested. Thus in this study, an attempt was made to construct a better measuring device through two tests--one a measure of the visual recognition and the other a measure of the visual and auditory recall combined. It was thought that if some link could be established with recall later studies could delve into the different types of learning and thinking as they relate to eye movements.

Reinforcement during learning has been shown to affect where the subject looks. Studies by Nunnally and others[20] have shown that the mean time spent looking at a rewarded stimulus was significantly greater than that for other figures. Some investigators have also reported that operant conditioning affects where the subjects look. In addition, White and Plum,[24] in a study of trial and error learning, noted that eye movements increased in number as learning approached optimum and decreased thereafter. Brandt[7] reported eye-movement data for subjects solving geometry, algebra, spelling, and geography problems. He reported that certain subjects had fewer fixations, and fewer excursion type of eye movements per correct solution if they were superior in achievement than did their inferior counterparts.

None of the above-mentioned researchers has investigated the various types of eye-movement indices as they relate to learning. The present investigators surmised that since the MINS and NOMS of the pilot study were so highly related to intelligence they might also be related to the learning of the subjects. This was assumed because of the relationship usually found between standardized intelligence tests and learning as measured through achievement tests. Thus one purpose of the research was to study the relationship of recall to the eye-movement indices.

Relationship of Eye Movements and Intelligence

A relationship between eye movements and intelligence has been reported by a number of investigators. Anderson,[2] in a study of children while they were reading, found a difference in the eye movements of good and poor readers. However, when he partialled out the factor of intelligence, the difference no longer existed. Thus, intelligence was the contributing variable. Guba and Wolf[14] found a sizeable correlation between some of the eye-movement indices of subjects in the pilot study and intelligence as measured by the California Test of Mental Maturity. They found that MINS had a correlation coefficient with total IQ scores on that test of -.70, significant at the .01 level, and that NOMS correlated .61 with the same test, significant at the .05 level.

A major purpose of the present research was to attempt to verify this finding by including a sample with subjects of high, middle, and low intelligence levels and to test the differences in their eye-movement indices. Since children with intelligence as low as those found in the pilot sample of fourth graders had dropped out of school by the time of the grade levels used for this study (junior and senior high school), the sample was, of necessity, restricted to children with IQ scores ranging from 90 to 140. This was expected to influence the findings of the study since many of the major differences noticed in the first study were between high- and low-IQ subjects when the low-IQ subjects had scores in the 70's. However, it was felt that the testing of differences, even between groups usually considered average and above average on a normal curve, should give some indication as to whether intelligence is a factor influencing the eye-movement indices of subjects. A further purpose was to determine if the intelligence level of the children influenced where they looked.

Maturation and Its Relationship to Eye Movements

Maturation has also been shown in some studies to be a factor related to the eye-movement patterns of subjects. Studies which have been the most definitive in presenting information on this variable are those in the field of reading by Buswell,[8] E. Taylor,[21] S. Taylor,[22] and Gilbert.[13] Taylor's study in 1959 was the most comprehensive. He and other investigators from participating colleges made a national survey to collect normative data on children. In the report of his study, Taylor points out that considering fixations and span of recognition together, fixations have decreased 50% by grade 2.5, 75% by grade 5.5, and 90% by grade 9. The change in regressions lags approximately one year behind fixations in that a 50% decrease has occurred by grade 3.4, 75% by 6.2, and 90% by 10.4. Unlike fixations and regressions, a 50% decrease in duration has occurred by grade 2.7 but it remains constant at 55% between grades 4.5 and 8.5. Seventy-five percent of the change has taken place by grade 10 and 90% by grade 12.8. Buswell has stated that the eyes are fairly well stabilized by the age of 10. Thus few differences might be expected after that time. However, Taylor's data indicate some differences at the upper grade levels, although in his studies most of the changes in eye patterns had occurred before the junior high school. His findings show that from first grade through college there is a change in eye-movement patterns and that in the upper grades there are fewer fixations, fewer regressions, and shorter pause duration. One purpose of the present study was to determine if eye movement differences occur among subjects at different age levels while they view the stimulus fields of motion pictures and television. These fields are quite different from reading. The analysis would include not only the differences in types of indices but also differences in where the subjects look. Such analyses should help producers to determine what, if any, adjustments are needed for age-level differences.

Stimulus Variables as They Influence Eye Movements

What one encounters, in a psychological sense, is dependent first upon the probability of physiological contact and second upon the probability of detecting what is contacted. The probability of physiological contact is dependent, in large part, upon the physical characteristics of the stimulus. It has been reported in various types of visual search that some areas or objects of the stimulus are virtually ignored while others receive a large amount of eye fixations (Enoch,[10] Guba and Wolf,[14] Mackworth and Morandi,[18] and Tuddenham and Calvert[23]). When the individual attends to his visual world, he tends to orient his eyes in the direction of his center of attention. While attention is not synonymous with visual orientation, since it is an inner state of the organism (a state of cognition), it can be assumed that when the organism is attending to his visual world, the center of visual orientation could be used as an indicator of the focus of attention.

One objective stated in the research proposal was to determine how different types of films might affect the eye movements of children. During the course of the study, research by other investigators and experience of the present investigators led to a classification of the scenes on the basis of various variables. The differences in eye movements between such scenes were then tested for significance.

<u>What stimulus variables influence visual orientation?</u> Various investigators have shown that certain properties of the stimulus have immense importance in attracting the eye fixations of the subject. Stimulus complexity and novelty are two such properties (Berlyne,[3,4] Faw and Nunnally,[11] Mackworth and Morandi,[18] and Mooney,[19]). According to these researchers, subjects spend more time looking at the more complex and more novel stimulus of a pair. In another study supporting the importance of complexity, Zusne and Michels[28] have also shown that angular complexities in polygon shapes attract more fixations than do straight lines. It should be noted that complexity attracts more eye fixations only up to a point. When the stimulus becomes extremely complex, the subjects may tend to avoid the stimulus or to fixate centrally.[14]

Among the other factors which appear, from the literature, to influence the probability of visual contact are motion state,[5,17,25,26] size,[6,10] and position with respect to the individual.[7,9] Other factors related to the contrast of the stimulus with its surroundings are also important. In the pilot study no significant differences were found between subjects' eye movements on static and dynamic scenes, but the scenes were compared from only one telelesson which had a minimum amount of movement.

Most of the studies on variables affecting eye patterns have used reading materials, still pictures, or simple fields such as a single light source as the stimulus. These fields differ from motion pictures and television in that the latter two fields are more complex and knowledge about any single variable by itself does not give information about the variable in relation to the highly complex field. In this study, the field was purposefully left unstructured so that eye-movement responses of subjects in a naturalistic setting could be evaluated. Thus it was not the purpose of this study to obtain highly specific and controlled data on only one stimulus variable. Because of the numerous variables to be considered, as well as the expense of constructing motion pictures and television lessons, it was decided that a more fruitful study would be one in which an attempt was made to determine which variables need to be researched. Later the nature of each variable could be verified through a controlled study. This research was exploratory in nature, with the control coming from sorting out the scenes so that they were as carefully defined as possible as to the variables contained within them. In this way, scenes which were similar could be categorized and their influence on eye movements compared.

Of the variables mentioned here, it was possible to include complexity, novelty, and motion state. The other factors could not be included because of their variability within a film. In addition, certain other factors which various educators have indicated to be important were included, as well as those variables which appeared to influence visual orientation in the pilot study. The variables on which the scenes were categorized are presented below with their definitions.

1. Motion State. Static--having no movement within the scene. Dynamic--having movement within the scene.

2. Complexity. Simple--having single elements or single elements added to a simple scene previously presented. Complex--having numerous elements.

3. Novelty. Familiar--previously present in a scene or an object commonly seen in the environment. Generally assumed to be recognizable in a brief glance by most individuals. Novel--an object unfamiliar because it is commonly seen in the environment and has not been presented earlier in the film. Generally assumed to require close study for identification.

4. One Type of Movement. Reversal--foreground appears to be moving but actually the background is moving. No-reversal--foreground is moving.

5.	Clarity.	Clear--all objects are in sharp focus. Unclear--some or all objects are hazy and fuzzy in appearance.
6.	Number of Attention Centers.	Unicenter--having a single conceptual center to which visual attention is directed. Multicenter--having several conceptual centers.
7.	Ambiguity of Meaning.	Ambiguous--visuals having possible multiple meanings. Unambiguous--visuals having a single meaning.
8.	Unity of Elements.	Distractive--has several objects which are not central to the purpose of the scene. Integrative--only relevant components are included.
9.	Arousal Characteristics.	Tranquil--scene has only a small amount of movement of the objects and the audio is presented through a normal pitched voice. Arousal--scene has a great amount of movement of numerous objects and the audio is raised high in pitch and frequency.

In addition, some scenes were classified as to the type of audio used. The audio was classified as (1) not related to the stimulus, (2) related to the stimulus with direct reference such as "this wing" with the narrator pointing, and (3) related to the stimulus with indirect reference such as "A line runs from the front to the back of the aircraft."

It was hypothesized that any change of the visuals might involve a change in the eye-movement indices or patterns of viewing. The visual orientation may be accounted for by considering a large number of interacting stimulus, and subject, variables. One purpose of this research was to attempt to sort out those stimulus variables which make a difference in the eye-movement indices and patterns of viewing. Specific purposes with regard to the stimulus variables were (1) to determine the differences in the eye-movement indices of subjects for scenes with different types of classifications, and (2) to determine where subjects look when scenes with different classifications are presented.

CHANGES DUE TO METHODOLOGICAL DIFFICULTIES

Before analysis of the data could be undertaken, it was necessary to transfer the data from film to computer tape. In order to perform this function and since this project was begun at a time when the United States Office of Education was not authorized to finance equipment for projects, a commercial firm was hired to perform the data read-out. A specification from the firm was that the eye marker had to be 25% brighter than the stimulus film. In order to meet these specifications, modifications to the experimental system were necessary to boost the brightness of the eye marker. This requirement eliminated the possibility of testing one of the hypotheses posed as a result of the pilot study; i.e., that of the "blooming" of the eye marker. Any time "blooming" occurred, the eye marker became larger and more diffuse and thus the specification of brightness could not be met. As a result, it became necessary to electronically control the eye marker brightness. This eliminated the possibility of checking the "natural blooming" of the marker since the element of diffuseness, in addition to size, was necessary to identify when this phenomenon occurred. Most eye markers change in size at some time during the viewing, depending upon the location of the marker in the stimulus field; for example, those markers toward the periphery of the field were a different size than those toward the center. When the "blooming" phenomenon occurred, however, the marker not only enlarged, but it also became quite diffuse. The electronic changes to meet the read-out specifications eliminated this diffuseness and, therefore, the "blooming" phenomenon was eliminated from consideration in the present study.

PURPOSES

After the changes in the study, the purposes of the project were as follows:

1. To verify whether a continuum of eye movements exists for subjects viewing dynamic bi-dimensional fields.

2. To determine whether there are significant differences in the eye-movement indices of subjects of different age and intelligence levels to varying stimulus materials.

3. To determine whether recall of the stimulus materials is related to the eye-movement indices.

4. To determine whether there are significant differences in subjects' eye-movement indices between scenes with different variable classification.

5. To determine where the subjects look on the various scenes; i.e., which objects receive their "attention."

6. To determine whether various scene variables such as novelty, complexity, and motion state affect where the subjects look.

7. To determine whether subject characteristics (including age and intelligence) influence where the subjects look.

Specific questions asked were as follows:

1. What types of eye-movement indices are observed in the data? Is there a continuum of movement or do the indices fall into the fixations and saccades often reported in the literature by other educational researchers?

2. Are there differences in the eye-movement indices of subjects of varying age and intelligence levels across all stimulus materials?

3. Is there a relationship between the subjects' recall of the stimulus materials and the eye-movement indices they display? If so, which eye-movement indices are related to recall?

4. Are there differences in the eye-movement indices for different stimulus films; specifically, for the following four types: (1) educational films which depend heavily on a visual presentation in which a lecturer or narrator is rarely visible; (2) educational presentations which depend heavily on a narrator or lecturer; (3) a general presentation with a fast-paced sequence and visuals of many different types; and (4) a commercial presentation in which the emphasis is on selling a product?

5. Are there differences in the eye-movement indices between scenes with different variable classification?

6. What elements of the scenes influence the subjects' "attention"?

    a. Do the type and number of objects affect the pattern of viewing?

    b. Is movement a factor influencing this "attention"?

    c. Is the audio a factor influencing where the subjects look?

    d. What other characteristics of the scenes affect where the subjects look?

CHAPTER II

PROCEDURES

OVERVIEW OF THE EXPERIMENTAL SESSIONS

Because of the delay in the beginning of the data collection phase of the experiment, it was necessary to run experimental sessions during the students' summer vacation. This caused slight attrition to the pool of available subjects. Appointments were made with each subject at his convenience. Each subject was picked up at his home and transported to the laboratory by staff personnel. En route the subject was shown a picture of the experimental apparatus and instructed as follows:

> We are interested in studying television, especially the kind of television shown in schools. You will be watching an educational television lesson. We are studying what you see and to find this out we will take a picture of your eye. Naturally, this is a difficult thing to do and in order to do it you will be wearing a helmet with a special camera on top.
>
> Here is a picture of a boy wearing the helmet we use in this experiment. We will show you the helmet and how it works when we get to the University. The camera sees your eye through that tube called a periscope. You will notice that the boy in the picture has something in his mouth. It is called a mouthpiece, and that particular one was made just for him. The reason you need a mouthpiece is so that the camera on the helmet doesn't jiggle around. As soon as we get to the laboratory we will make a mouthpiece for you.

Metal mouthpieces covered with dental compound had been made in advance. As soon as the subject had entered the laboratory and had been introduced to the staff personnel, he was assigned an experimental number and his dental impression was taken. While his mouthpiece was being cooled and trimmed, the subject was acquainted with the apparatus. He was shown the television set and allowed to handle the helmet and sit in the experimental chair with the helmet resting on his head while the recalibration motors were demonstrated.

The mouthpiece was then attached to the helmet and the helmet fitted to the subject. The eye marker was found, focused, and calibrated on a small dot placed in the center of the television screen. The following instructions were then given to the subject:

> Now we are ready for the television presentation which will last about 20 minutes. You will see some short programs of an educational nature and maybe even a commercial. We are

on closed-loop TV, which means that this program is being sent from near here on the University campus. We have asked the TV station to interrupt the program 7 times so that we can photograph your eye. While we are taking that picture you will see a small circle with 4 lines out from it right in the middle of the TV screen. We want you to look right at the circle and concentrate on the center of it. When the circle is gone from the screen, and for the rest of the time, we want you to watch the presentation just as you would one at school. We want you to relax and enjoy it, but we want you to pay attention too. I'll turn the set on now and let you watch the program.

When the experimenter turned on the TV set a small light went on in the control room indicating to the controller to start the video tape recorder. The experimenter then sat quietly in the experimental room during the session in order to make any corrections or modifications directed by the controller via the intercom.

Two persons, one the controller and the other an observer, remained in the control room throughout the session. The controller continuously monitored the eye marker and made adjustments in addition to performing the recalibrations by remote control when fixation targets were displayed on the screen. Recording of data with a motion picture camera (operating at 24 frames per second) was begun at the second recalibration target inserted into the stimulus material and was terminated after 600 feet of film had been exposed.

After the television presentation, the tester established rapport with the subject, escorted him to an adjacent office, and administered the two post-session tests. Each set of test instructions was read to the subject just before he was given that particular test. Upon completing the post-tests, the subject was driven back to his home by staff personnel. The entire experimental session required one to one and one-half hours.

SAMPLE

A convenience sample of subjects had been selected from students enrolled in grades 6, 8, and 11 of the Columbus, Ohio, public schools. All students in the entire grade level at an elementary school, a junior high school and a senior high school formed the original candidate population. On the basis of school records, the subjects were screened to eliminate those who wore glasses, had defective hearing, or exhibited some other physical or behavioral anomaly which would interfere with data collection. Subjects whose ages were more than four months above or below the mean of their age-grade group were initially rejected, although age ranges had to be slightly extended later. Letters were sent to parents of each child requesting permission for their child to participate in the study (Appendix A). On the basis of Henmon-Nelson

IQ tests administered and furnished by the schools, subjects were then grouped as follows: 85-99, the lower IQ group; 105-114, the middle IQ group; and 120-140, the upper IQ group.

With the cooperation of professional assistants from The Ohio State University School of Optometry, a comprehensive eye examination was administered to each candidate. The measures taken included visual acuity, retinoscopy, phoria, ophthaloscopy, and stereopsis. A sample of the optometric examination sheet is presented in Appendix B. Those candidates failing to meet minimal visual requirements for good, uncorrected vision or falling more than one standard deviation from the norm for specific measures were rejected from use in the sample. The experimental design consisted of three grade levels with three IQ groups in each level. A total of 54 subjects were required to provide six subjects in each of nine cells. To allow for attrition, a pool of 9 to 12 available subjects per cell was established. Ultimately, 71 subjects completed the experimental sessions.

Although the data films appeared excellent in quality when viewed by the human observer, the read-out agency found they could not handle many of them. Officials of the agency had been shown sample films prior to the experimental sessions and had indicated that reading the films would create no difficulties. However, the natural varying brightness of both the eye marker and the stimulus background from frame to frame in the data films did present a great problem for the electronic film reader. This problem will be explained in the data transcription section of this chapter. The initial sample requirement of 54 subjects was extended to 71 in an attempt to obtain the type of film that could be transcribed. From this group of data films, the 54 which afforded the best read-out possibilities were selected and sent to the agency. Eventually, because of the electronic difficulties, only 26 subjects comprised the sample. The total number of frames involved in the sample for read-out and data analysis was 18,600 frames for each subject multiplied by 26 for the number of subjects or a total of 483,600 frames involved in the total data sample.

The mean scores on age and intelligence of subjects in the final sample did not differ substantially from the initial sample for this study, as can be seen in the following tables. The project staff wanted to include children with much lower IQ's than those in the lower IQ group; however, this was an impossibility since children with intelligence scores as low as those found in the pilot study (scores in the low 70's) had dropped out of school by the junior high school level.

Table I - Mean Ages for Each Group in the Initial Sample

Grade Level	Intelligence Levels		
	Upper	Middle	Lower
6	11 yrs, 7.4 mos	11 yrs, 8.9 mos	11 yrs, 10.3 mos
8	13 yrs, 7.5 mos	13 yrs, 6.6 mos	13 yrs, 6.8 mos
11	16 yrs, 8.8 mos	16 yrs, 7.5 mos	16 yrs, 7.9 mos

Table II - Mean Ages for Each Group in the Final Sample

Grade Level	Intelligence Levels		
	Upper	Middle	Lower
6	11 yrs, 7.8 mos	11 yrs, 9.1 mos	12 yrs, 1.2 mos
8	13 yrs, 4.2 mos	13 yrs, 4.7 mos	13 yrs, 5.0 mos
11	16 yrs, 7.2 mos	16 yrs, 6.4 mos	16 yrs, 3.9 mos

Table III - Mean Intelligence Quotients for Each Group in the Initial Sample

Grade Level	Intelligence Levels		
	Upper	Middle	Lower
6	126.0	108.0	95.3
8	131.0	111.1	93.5
11	132.0	109.5	94.8

Table IV - Mean Intelligence Quotients for Each Group in the Final Sample

Grade Level	Intelligence Levels		
	Upper	Middle	Lower
6	128.3	107.3	93.0
8	132.0	108.7	96.0
11	125.0	110.0	94.7

CRITERION DATA

Two types of criterion data were obtained; i.e., scores on the subjects' recall of the stimulus films and scores on intelligence. Special tests were constructed to measure the subjects' recall and understanding of the stimulus; however, the intelligence test scores were obtained from school records.

Post-Tests

Two tests were constructed to measure the subjects' recall of the stimulus films. One of the post-tests measured the subjects' recognition of the visual portion of the stimulus. This test was entitled Visual Recognition (VR) and consisted of 21 plates, the plates containing from two to four drawings each. For each plate, the subject was asked to select the drawing which was the most like some scene he had seen in the television presentation. The second test, entitled Visual and Auditory Recall (VAR) consisted of 33 true-false items and emphasized understanding as well as recall based upon an integration of the visual and auditory portions of the films. The two tests represent the content for the three films Weather, Piloting, and Water. The commercial was excluded from consideration on this portion of the research.

Representative plates from the VR test and sample items from the VAR test are included in Appendix C. The instructions given to the subjects prior to administration of each test are also presented in that appendix.

The reliabilities of the two tests are shown below. They were obtained by using a split-halves technique for determining reliability and the Spearman-Brown prophecy formula for estimating the reliability of a whole test from that of its halves.

	Pearson Product Moment	Spearman Brown Prophecy Formula Correction
VR	0.68	0.80
VAR	0.72	0.84

These reliabilities were considered satisfactory by the project staff since the tests developed were different from others available and thus no other tests could serve as models.

In order to determine the degree of agreement between the distributions on the tests and theoretical distributions, the Kolmogorov-Smirnov one-sample test of goodness of fit was applied. The D obtained for the VR test was 0.1177 with an N of 12, and the D for the VAR test was 0.1200 with an N of 19. Both of these tests showed that the sample scores were not significantly different from those of a theoretical population (Appendix D). Frequency polyg. ms for these scores also showed that were the sample larger, the distribution would tend toward a normal curve.

Satisfactory difficulty levels were established for the various items on the VR and VAR tests. However, the VR test was more difficult for the subjects than was the VAR test. Most of the items also discriminated fairly well between the top 25% and the bottom 25% of the sample based on the test totals. Both the difficulty and discrimination scores for the items are presented in Appendix E.

Subject data are given in Appendix F. The scores for each of the 26 subjects on the VR and VAR show that the range of scores on the VR test was from 7 to 18 from a potential 21. The mean for this test was 12.6 and the standard deviation 3.0. On the VAR test the range of scores was from 16 to 33. Only one subject obtained 33. This perfect score indicates that the ceiling for the test was not high enough. A mean of 24.2 and a standard deviation of 4.5 also show that the test was fairly easy.

Intelligence Test

The Henmon-Nelson group intelligence test was administered in the public schools a few months prior to the experiment. Scores from this test were obtained and used as the intelligence scores for this research. These scores also appear in Appendix F.

STIMULUS MATERIALS

Criteria for selection of the stimulus materials for this study were developed in large part from some of the eye-movement responses of children viewing the pilot stimulus. Those findings and their effect on the criteria were as follows:

(1) Children's eye movements did not appear to be related to the type of scene, but rather to subject characteristics. Since the pilot stimulus was restricted in terms of content, several quite different types of films were included as the stimulus in the present study to test this finding on a larger scale.

(2) Subjects often looked at the narrator's face in the stimulus film even to the exclusion of demonstration material. To test for differences in presentation with and without a narrator, two educational presentations were included in the stimulus film for this study. In the first presentation, a narrator talked and demonstrated.

The second film paralleled an observational situation with the narrator completely off screen and with the concepts presented visually with audio support.

(3) In a fast-paced sequence in the pilot study, the subjects limited their eye movements to a relatively small central portion of the screen when the scene became dynamically complex. Another fast-paced sequence was to be included in this study in an attempt to replicate that finding.

An additional criterion for the selection of the stimulus was that there should be a variety of visuals used in the various films.

Thus, the following four types of stimulus segments were selected: (1) an educational presentation which depends heavily on an on-screen narrator or lecturer, (2) an educational presentation which depends heavily on visual presentations and in which a narrator is rarely or never seen, (3) a more general presentation with a fast-paced sequence and with visuals of many different types, and (4) a commercial presentation in which the emphasis is on selling a product. Further selection criteria included the following: (1) the combined films needed to be of a reasonable length to avoid subject fatigue, preferably not more than 20 minutes based on experience from the pilot study; (2) the content should be appropriate to the interest of all age levels of children included in the study and should be understood by all of them; and (3) all films, with the exception of the commercial, should be fairly unique, i.e., not commonly used in the public schools nor seen on television at home and thus films which the subjects had not seen before.

Numerous directors of television centers and motion picture film centers were contacted for assistance in selecting the stimulus. Initially, a letter was sent to these centers specifying the criteria and asking for a list of potential films and kinescopes. The following centers were exemplary of the ones contacted through a letter or in person.

1. National Film Board of Canada
2. Encyclopedia Britannica Films
3. Instructional Television Library* including the National Instructional Television Libraries in New York, Nebraska, Massachusetts, and Michigan
4. The Ohio State University Audio Visual Communication Center

* Later became the National Center for School and College Television, Bloomington, Indiana.

5. Center for Mass Communications of Columbia University

6. National Educational Television Library

In addition, some independent producer-directors were contacted.

The project staff reviewed all of the suggested films and kinescopes which appeared to meet the criteria. From among these films, the following were selected:

1. Origins of Weather, Encyclopedia Britannica Films, Inc., Chicago.

An educational film with a narrator not visible; had won an educational film award.

2. Piloting and Control of an Airplane, KCTS-TV, Seattle.

An educational telelesson with a visible narrator.

3. Water, Center for Mass Communications, Columbia University.

A presentation with a fast-paced sequence having many types of visuals and changes in the pace of the audio.

4. An Ajax Commercial, New York Advertising Agency.

In order to meet the criteria of length, the combined films were edited to a total of approximately 19 minutes. The editing was done in such a manner that it was impossible for the subjects to tell where the editing had occurred. The stimulus film was then converted to a video tape for presentation on a television monitor. A scenario of the edited stimulus film is presented in Appendix G. The scenario contains a description of the visual components of the scenes plus the auditory commentary.

In order to determine if the scene variables described and defined in the problem statement affected the eye movements, each scene was classified on the variables of motion state, complexity, novelty, clarity, number of attention centers, ambiguity of meaning, unity of elements, and arousal characteristics. In addition, some scenes were classified on the audio as follows: (1) not related to the stimulus, (2) related to the stimulus with direct reference or (3) related to the stimulus with indirect reference.

The classification of these scenes was made by a panel of judges consisting of five project members. Each scene was viewed with a stop-frame projector. The judges rated each scene on a two-point scale for each of the variables. For example, if the scene were static, it received a rating of "0" on the variable of motion; it it were dynamic, it received a rating of "1" on the same variable. When the rating sheets were compared, any discrepancies were resolved by a review of the scene. In cases of further disagreement, the majority ruled. Unanimous ratings were common for most of the variables across scenes.

For the purpose of correcting and recording error in the eye marker's position, six recalibration targets of ten seconds duration were spliced into the stimulus film. Subjects had been instructed to fixate the recalibration target when it appeared. These targets were interspersed at approximately two-minute intervals throughout the film and were placed such that they interfered as little as possible with the content. For example, several targets were placed at the beginning of the various films.

The subject's eye markers over the stimulus film were recorded onto data film for only 16 of the 20 possible minutes--the first $2\frac{1}{2}$ and the last $1\frac{1}{2}$ minutes were omitted. This was done to eliminate the parts where the subject was adjusting to the film and where the subject might be fatigued. Eye-movement responses to scenes numbered from 2.01 to 41.0 in the scenario (Appendix G) were selected for read-out and given to a commercial firm. This entailed approximately 13 minutes of eye-movement data or 18,600 frames of data for each subject.

THE CORNEAL REFLECTION TECHNIQUE

The outer surface of the cornea approximates a portion of a spherical surface from which light can be reflected. This spherical reflector rotates about a point (the center of rotation of the eye) which does not coincide with its center of curvature. As a result, this corneal reflector is displaced very slightly as the eye rotates during eye movements. This displacement of the spherical reflecting surface results in a change of the angle of reflection of light striking the cornea.

Eye-movement data are obtained by focusing the reflected image of a point light source onto a recording surface. The position of this focused, reflected image ("eye marker") will shift as the eye rotates, indicating the eye movement. The relationship between eye marker position and the angle of rotation of the eye is essentially linear up to about ± 10°. A direct relationship can therefore be established between the focused eye marker and the subject's line of sight.

THE EYE-MOVEMENT APPARATUS

The corneal reflection apparatus used in this study was a modification of that developed by Mackworth.*

*As reported in Mackworth, N. H.; Llewellyn-Thomas, E.; and Holmquist, S.. "The Television Eye Marker on a Changing Visual World," Visual Search Techniques, Morris, A. and Horne, P., eds., Washington, D. C.: National Academy of Sciences - National Research Council Publications, (19 0).

In the Mackworth Eye-Movement Camera, the point light source is attached at the bottom of a hollow tube and positioned in front of the subject's left eye. The light from this point source which is reflected by the cornea is transmitted up the tube and focused onto the film plane of a motion picture camera. This camera then records the eye-movement data.

Since all of this equipment is attached to a helmet worn by the subject, he is relatively free to move his head without affecting the eye-movement data. That is, with the helmet securely attached to the head the position of the apparatus in relation to the eye is not changed by head movements and no change in the position of the eye marker on the recording surface results.

As described this far, the apparatus makes possible the recording of movements of the eye in its orbit and these data are independent of movements of the head. In order to now determine where in his environment the subject is looking, the position of the head must be taken into account. The Mackworth apparatus accomplishes this in a simple and direct way. A second optical system attached to the helmet is used to obtain an image of the subject's visual field, and this image is focused onto the recording surface along with that of the eye marker. By proper calibration of the apparatus, the image of the eye marker can be superimposed onto that of the visual field in such a way that the combined image indicates directly what the subject is viewing. This basic system is illustrated in Fig. 1.

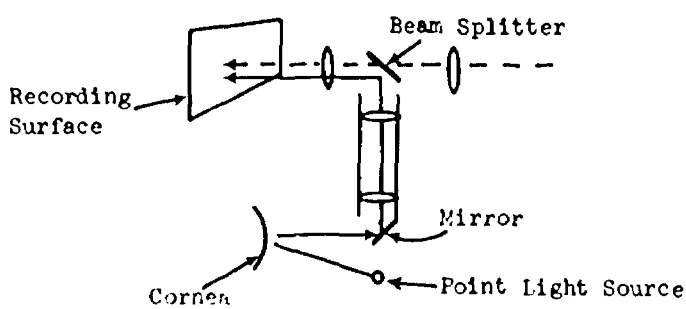

Fig. 1 - Basic Eye-Movement Apparatus

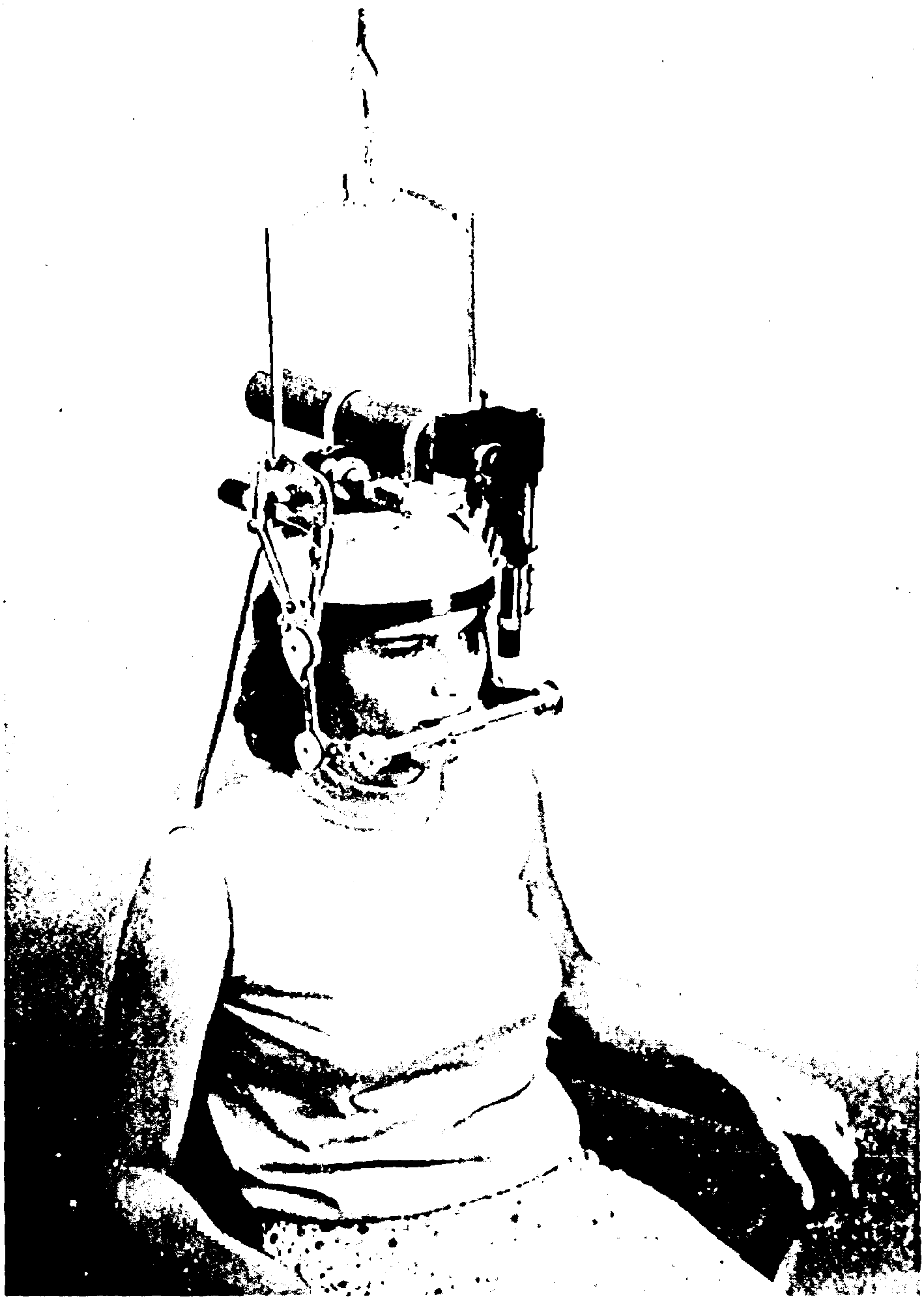

Fig. 2 - The Eye-Movement Apparatus Helmet

Several major modifications were made to the helmet apparatus since the pilot study. It is illustrated in its present form in Fig. 2. The vidicon tube of a transistorized television camera (Dumont Laboratories) is used as the recording surface. This makes possible extended periods of uninterrupted data recording, with the progress of the experimental session observable on a television monitor. A permanent data record is made with a motion picture camera from another monitor connected to the vidicon camera. The adjustable downward extensions from the helmet are used with a bite bar to which is attached a hardened dental impression of the subject. This secures the helmet to the head through the upper dental arch. The apparatus is mounted on a movable platform on top of the helmet which can be driven in any direction by three remotely controlled motors for adjustment and calibration purposes.

DATA RECORDING

The direct superimposition of an image of the subject's visual field and the eye marker allows the resulting data films to be projected for direct viewing. However, in order to facilitate the transcription of the data from film to computer tape, the eye marker must appear appreciably brighter than the background image of the visual field. Since the corneal reflection light source must be kept at a low level for subject comfort and the vidicon camera was not sensitive enough to display the resulting eye marker with the required brightness, a suitable video amplifier had to be constructed. This amplifier, designed by the Harron Instrument Company, allowed the video signal above a variable threshold level to be driven to saturation. During the data recording session, the unmodified picture was observable on one monitor while a second monitor displayed the modified picture. An oscilloscope displayed the unmodified video signal and the variable threshold level. By adjusting the threshold level of the video amplifier to compensate for the varying brightness of the various stimulus sequences and occasional changes in eye marker brightness, it was possible to produce a modified picture in which the eye marker appeared as a white spot superimposed on a dimmer image of the visual stimulus.

The modified video signal was displayed on a third monitor where it was recorded by a 16 mm motion picture camera. This camera (Bach-Auricon) model was equipped with a special television transcription shutter to record the television image at 24 frames per second without the appearance of synchronization lines. The resulting data films were then transcribed to computer tapes for further analysis. The data recording system is shown in Fig. 3.

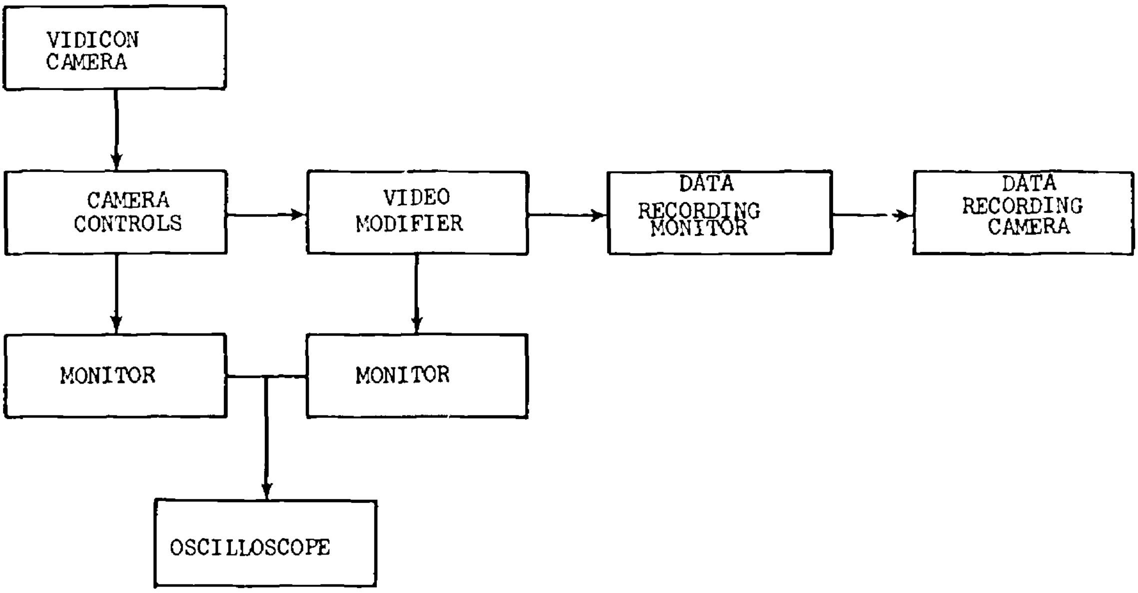

Fig. 3 - Data Recording System

DATA TRANSCRIPTION

Figure 4 is an example of one frame from a data film. The four outer markers delineate the stimulus area in the subject's visual field while the eye marker superimposed over the stimulus indicates where the subject is looking. Because the subject was free to move his head, the stimulus field does not appear as a perfect rectangle on the data film. As a result of such perspective distortions, size and shape of the stimulus field on the data film are highly variable.

The first step in data transcription from film to tape is the conversion of the image into a standard reference frame which is independent of the subject's position with respect to the stimulus field.

To achieve the desired transformation to a standard reference system, the corners of the stimulus field must first be identified as they appear on the data film. The parameters for a transformation equation are calculated next. This transformation can then be applied to any point in the original data film frame in order to map it into the standard (transformed) reference system. As a result, the effects of the subject's

Fig. 4 - Data Film Frame

(Enlarged from 16 mm Motion Picture Frame) head position and position of the eye marker within the stimulus field are compensated for to yield a set of angular coordinates for the eye marker in a standard reference system. In this reference system the visual field of 300 by 230 units forms the coordinate system within which eye marker position is measured in units of 1/20° of arc.

After (1) the corners of the stimulus field have been sucessfully identified and (2) the transformation equation has been determined, it is now necessary to (3) identify the eye marker within the stimulus image and (4) transform its position into the standard coordinates. Each of these four steps must be repeated for each separate frame of data film for which data are to be transcribed. An efficient automated method of data transcription is obviously essential.

The data transcription system consisted of a film scanner which was under computer control. The film scanner is capable of measuring film image density at a specified point within each film frame over a grid of 512 by 512 points. The density measurement is on a two-point scale of ABOVE and BELOW with respect to a specified reference level. The basic data available through the computer program controlling the film scanner are ABOVE/BELOW indications for each of the more than 262,000 points within a film frame that it may interrogate.

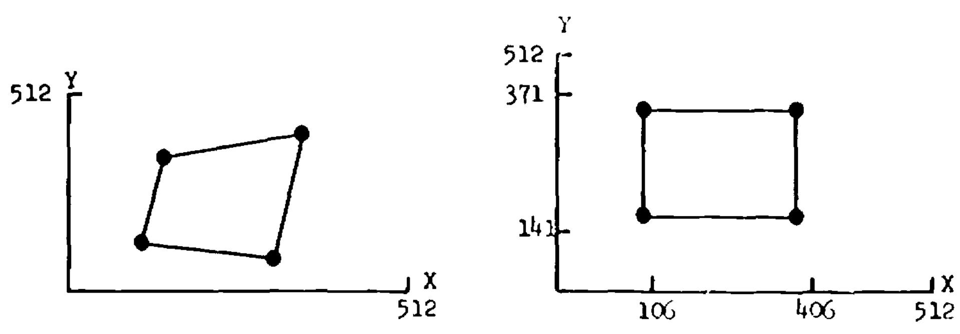

Fig. 5 - Data Reference Systems

Although the corner markers delineating the stimulus field and the eye marker superimposed on the stimulus image were to be considerably brighter than anything else appearing within a data film frame, this could not be consistently achieved. This contrast ratio requirement became an acute problem after failure of the vidicon camera necessitated extensive rebuilding of its circuitry. Subsequent performance of the vidicon camera was marginal for most of the data-recording sessions. In addition, some subjects displayed wide variations during a session in the brightness and shape of the corneally reflected eye marker. These two factors, coupled with the large brightness variations occurring in the stimulus material, resulted in a large number of data films in which the markers were not considerably brighter than everything else appearing in the data film image. Furthermore, even when the eye marker and the markers delineating the stimulus field were relatively brighter than the remainder of the image, the natural variations in marker brightness, both between and within data films, were considerable.

The first film-scanning program was based on two concepts; i.e., (1) a specified threshold above which any point appearing in a data film frame was to be considered as either a part of the eye marker or one of the four stimulus field markers, and (2) markers that were essentially circular in shape. The wide variations in eye marker shape, together with the noise within the video signal, yielded totally unsatisfactory results in the initial attempts at transcribing data from the films.

A new program was developed which was able to perform satisfactorily. The basic data available to the program were still solely the ABOVE/BELOW measure for each point interrogated within the data film frame image. The capability to alter the threshold setting under program control was added and the basic ABOVE/BELOW data were much more extensively analyzed. In addition to brightness, the size, shape, and location of potential marker identifications were added to the criteria used in the new program to identify the actual markers among all possible candidates. A further major improvement was achieved by using a predictive algorithm, based on the actual characteristics of markers identified on immediately preceding frames, to locate the markers on the next film frame to be read. With the large possible variations in marker characteristics, various elements in the stimulus image were frequently mistaken for markers in the initial film reading program. By predicting not only the characteristics but also the positions of markers, the revised program performed quite reliably. One of the problems which was not satisfactorily solved resulted from the "lag" typical of vidicon tubes when operated near the feasible limit of sensitivity. With a sudden change in the image, the previous image is not replaced immediately by the new image as viewed on the monitor, but rather slowly fades as the new image is established. As a result, when the eye makes a quick saccade both the old and new eye markers may appear on the same frame. Since the image of the old marker may even be brighter than that of the marker actually present, an incorrect identification can result. This problem was minimized by backtracking whenever the eye marker was identified at some distance from its position on the preceding frame. At this point the program checked whether the eye marker had not shifted to this new position prior to the point at which it had last been found at the old position.

The three types of errors examined for the resulting data tapes used in analysis were (1) repeatability, (2) absolute error, and (3) relative error. Repeatability of the film-scanning program was established by reading a section of 100 frames three times and examining the variation in eye marker coordinates among the three readings. The mean absolute variation among the three readings was approximately 1 scanning unit (1/20°) with a standard deviation of almost 0.9 units.

The second source of error in the final data is absolute error in the position of the eye marker resulting from misalignment of the helmet-mounted apparatus. Since a displacement of the apparatus with respect to the eye is indistinguishable from a displacement of the eye with respect to the apparatus, both are recorded as an eye movement on the data film. A 5° rotation of the eye displaces the cornea slightly more than one millimeter; conversely, one millimeter of helmet slippage is recorded as several degrees of eye movement. An indication of the magnitude of this source of error was obtained by examining data recorded on the calibration targets (see discussion under Stimulus Materials). Examination of the data indicated that this error was fairly minimal for the films used in the final sample.

Relative error here refers to the error in the distance between eye marker positions on a pair of successive data film frames. It is mentioned here primarily to point out that it is largely independent of the absolute error in eye marker position resulting from helmet slippage, which tends to remain stable over a large number of film frames and to change only occasionally.

THE DATA TAPES

The computer tapes produced by the film reader during data transcription included the following information: (1) coordinates of the eye marker (1/20° units) in the transformed reference system, (2) position and orientation of the stimulus field to indicate head position, (3) eye-marker diameter, and (4) an error code indicating quality of data or reason for missing data; e.g., blinking of the eyes.

A printed listing of these data was reviewed, together with each data film, on a frame-by-frame basis to correct data where necessary for proper merging into a master tape and to reject data which required another pass through the film reader. A total of 26 films was finally accepted for inclusion in the data sample. Data for these films were largely complete, although in a few instances some sections of data which could not be properly transcribed by the film reader were edited during review.

The edited tapes were then preprocessed and merged into a master tape consisting of the following data for each film frame: (1) coordinates of the eye marker in $\frac{1}{2}°$ units, (2) estimated average velocity of the eye marker between successive frames in 1/20° units, and (3) direction of eye-marker movement between successive frames in 6° units. The actual tape and data formats of both the film reader output tapes and the master tape are given in Appendix H.

PROGRAMMING

A library of programs was developed to aid in the preparation and analysis of the data transcribed from the film records. The SCATRAN language, previously in use at the University, was the main programming language, with many of the subroutines being written in FAP assembly language. Since these programs are not transferable, they will not be described in detail. The analysis of variance was made with one of the BIOMED programs developed at the University of California.

Much routine and repetitive programming was simplified by the development of interpretive packages. This approach allows the definition of pseudo programming languages whose concepts and vocabulary are familiar to the user for a specific problem area. As a result he need not be familiar with an actual programming language or be aware of the actual operations required to achieve his objective.

An example of such an interpretive package is a program referred to as the WPL language which was developed for density analysis. Here the primary questions are in terms of where do subjects look, how much time do they spend in looking at various areas in the stimulus field, and what is the velocity distribution for these data? To answer such questions by using WPL, the user need only know the meaning of such terms as density and density clusters, the VMAG distribution, and have available a scenario of the stimulus (see Appendix G) to identify the scenes or subscenes in which he is interested.

A WPL density plot simply indicates the percentage of time some specified sample of subjects spent looking at each point in the stimulus field which has been divided into squares of $\frac{1}{2}°$ of visual arc. An example of such a plot can be found in Appendix I. A WPL cluster plot not only indicates various levels of density, but further identifies larger areas within the stimulus field where the eye markers tend to fall into distinct groups and labels the points in the stimulus field falling within each cluster. An example of this can be found in Appendix I.

Since various definitions of clustering can be made, the one used in WPL will be described briefly. An outline of the algorithm reads as follows:

(1) START. For the specified stimulus sequence and subject

sample determine the eye marker density at each point in the visual field.

(2) Begin definition of next cluster. Find the point of highest (nonzero) density which has not yet been classified into a cluster. Classify this point into the current cluster. If no unclassified points remain available STOP.

(3) Select the point of highest (nonzero) density which borders the current cluster. If none remain the cluster is completed--go to (2).

(4) If the selected point has a higher density than the last point classified into the current cluster ignore it and go to (3). If the selected point has already been classified into another cluster delete it and go to (3). Classify the selected point into the current cluster and go to (3).

Clusters are arbitrarily labeled A, B, C, . . . and each point in the stimulus field will have been classified as blank (zero density), as belonging to some cluster (A, B, C, . . .), or as deleted (indicated by a dot in the printout). Deleted points are those which lie in a region of overlap between two or more clusters and therefore have not been classified into any cluster. Each cluster indicates a distinct grouping of eye markers.

An example of a graph of the eye marker velocity distribution can be seen in Appendix I. This was drawn on a CALCOMP plotter by using the WPL language.

CHAPTER III

DATA ANALYSIS AND RESULTS

INTRODUCTION

As stated in the problem statement, the objectives of this research were as follows:

1. To verify whether a continuum of eye movements exists for subjects viewing dynamic bi-dimensional fields.

2. To determine whether certain subject characteristics, including age and intelligence, influence the subjects' eye-movement indices.

3. To determine if different types of films influence the eye movements of the subjects.

4. To determine whether the eye-movement indices identified are related to the subjects' recall of the stimulus film.

5. To determine what elements of scenes across films influence the subjects' eye-movement indices.

6. To determine what elements of the scenes attract the subjects' attention.

7. To determine if subject characteristics such as age and intelligence are related to where the subjects look.

The following specific questions served as a basis for the data analysis:

1. What types of eye-movement indices are observed in the data? Is there a continuum of movement or do the indices fall into the fixations and saccades often reported in the literature by other educational researchers?

2. Are there differences in the eye-movement indices of subjects of varying age and intelligence levels across all simulus materials?

3. Is there a relationship between the subjects' recall of the stimulus materials and the eye-movement indices they display? If so, which eye-movement indices are related to recall?

4. Are there differences in the eye-movement indices for

different stimulus films; specifically, for the following four different types: (1) educational presentations which depend heavily on visual presentation and in which a lecturer or narrator is rarely seen, (2) educational presentations which depend heavily on a narrator or lecturer, (3) a general presentation with a fast-paced sequence and visuals of many different types, and (4) a commercial presentation the emphasis of which is to sell a product?

5. Are there differences in the eye movement indices between scenes with different variable classification?

6. What elements of the scenes influence the subjects' attention?

   a. Do the type and number of objects affect the pattern of viewing?

   b. Is movement a factor influencing attention?

   c. Is the audio a factor influencing where the subjects look?

   d. What other characteristics of the scenes affect where the subjects look?

DATA ANALYSIS

With these questions providing the general framework for the investigation, two types of analyses were performed. The first, the analysis of eye-movement indices, was conducted to answer questions dealing with the types of movements observed and the effect on the eye-movement indices of age, intelligence, subjects' recall, types of stimulus materials, and various elements of the scenes. The second, the descriptive analysis, was conducted to answer questions concerning where the subjects look and what elements of the scenes affect the viewing pattern. In addition, the influence of age and intelligence on these viewing patterns was determined.

Eye-Movement Indices

The eye-movement data obtained as a result of the data film transcription process consisted of coordinates of the eye marker within the stimulus field, sampled at the rate of the data-recording camera; i.e., 24 frames per second. Such eye-position data may be interpreted as eye-movement data by calculating an estimated average velocity from the eye position as recorded on two successive data film frames.

In the pilot study this was done by a visual examination of the data films. Eye marker velocity, as inferred from the extent of movement in terms of eye marker diameter, was observed to fall into a number of distinct intervals. These movements did not correspond to the dichotomy of fixations and saccades usually reported by educational researchers. Rather, a number of distinct categories were identified. These categories were termed indices. One purpose of the present study was to verify this continuum of indices.

In the present study, changes in the position of the eye marker could be measured on a finer scale than in the pilot study. Since coordinates of the eye marker were available in units of 1/20° of visual arc for each film frame, the unit of eye-movement measurement corresponded to 1/20° per 1/24 second. Thus the unit of measurement was approximately 1.2°/second in estimating the average eye marker velocity on the basis of the eye marker coordinates for each pair of data film frames. The overall distribution of velocities obtained is given in Fig. 6. The estimated average of velocities* occurs mainly at the low end of the continuum below 10 units (12°/second). As can be seen from Fig. 6, these data fall into a continuum of velocities.

This distribution was divided into four fairly distinct intervals to simplify eye-movement data classification. This choice of categories was based on both the classification developed in the pilot study and various analyses of the present data. An analysis of the sequential pattern of eye-movement velocities was a major factor in determining the various divisions. The distinct nature of these categories was supported later by the data analysis.

The definition of the resulting indices is given in Table V. This classification is similar to that found in the pilot study.

Table V - Definitions of Eye-Movement Indices

No Observable Movement	0 - 4.2°/sec
Minimovement	4.2 - 11.4°/sec
Small Saccade	11.4 - 47.4°/sec
Large Saccade	Above 47.4°/sec

*In Appendix H, the estimated average velocity is termed VMAG.

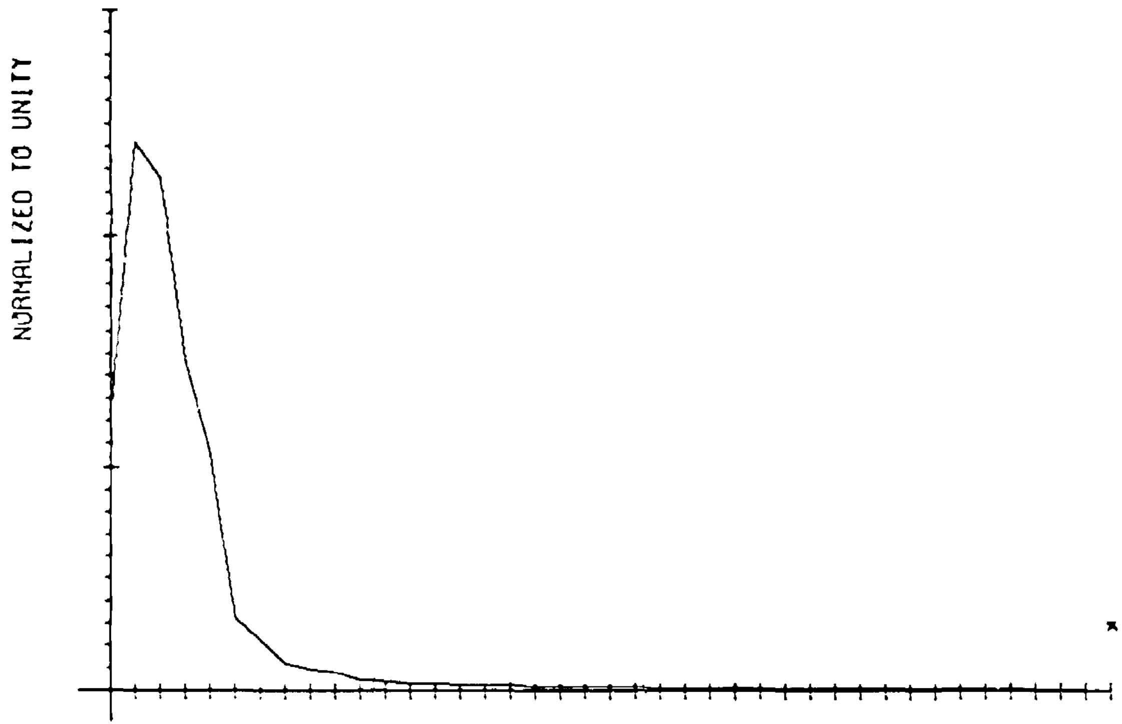

Fig. 6 - Mean Distribution of Velocities for All Subjects over the Four Films

Comparing these indices to the usual dichotomy of eye movements used by other researchers, No Observable Movement (NOM) corresponds to fixations, including tremor and slight forms of nystagmus, and the Saccades in the two classification schemes are also similar. Between these two extremes of the continuum lies the Minimovement category.

Velocities in the Saccade (SAC) categories are not very meaningful since these movements are generally completed within one pair of data film frames. Therefore, an accurate estimate of average velocity cannot be made on the basis of such data. Here it is preferable to speak of the extent of movement, rather than the estimated velocity, with Small Saccades ranging between ½° - 2° of visual arc and Large Saccades falling above 2°.

The general shape of the distribution of eye marker velocities is exemplified by Fig. 6. However, this distribution may change as a function of stimulus material and subject characteristics. For example, the distribution of eye marker velocities for a Static scene is illustrated in Fig. 7. In comparison, Fig. 8 illustrates the distribution obtained for a Dynamic scene. The portion of the continuum shown in these two graphs corresponds essentially to the NOM and MIN indices with Small and Large Saccades collapsed into a single point. The variability in these distributions between subjects is illustrated in Fig. 9. This graph should be compared to Fig. 8 where the mean of these distributions is presented.

Analysis

A three-factor analysis of variance was applied to the four eye-movement indices of NOMS, MINS, Small Saccades, and Large Saccades to test the effect on the indices of film differences, intelligence differences, and age differences. Results of the four analyses showed only one significant main effect which was on films for the index of Large Saccades (an F of 16.971 was obtained, significant at less than the .01 level with 3,54 df). The frequency of saccades on the films was highest on Water and then the descending order of frequency was on Ajax Commercial, Piloting and Control of an Airplane, and Weather. That no other significant results were found on this analysis was attributed to a possible washout effect since the analysis was over the subjects' eye movements for the entire stimulus. Thus, several more analyses were run to answer specific questions over shorter segments of data.

Correlational Analysis. A correlational analysis was conducted to determine if there were a significant relationship between subjects' recall of the stimulus and the eye movements they exhibited over the portions of the film from which the questions had been developed. In addition, a further exploration of the relationship between intelligence and the subjects' ages and the eye-movement indices was made. A multiple regression analysis (i.e., the Wherry Test Selection Method) was employed for this analysis.

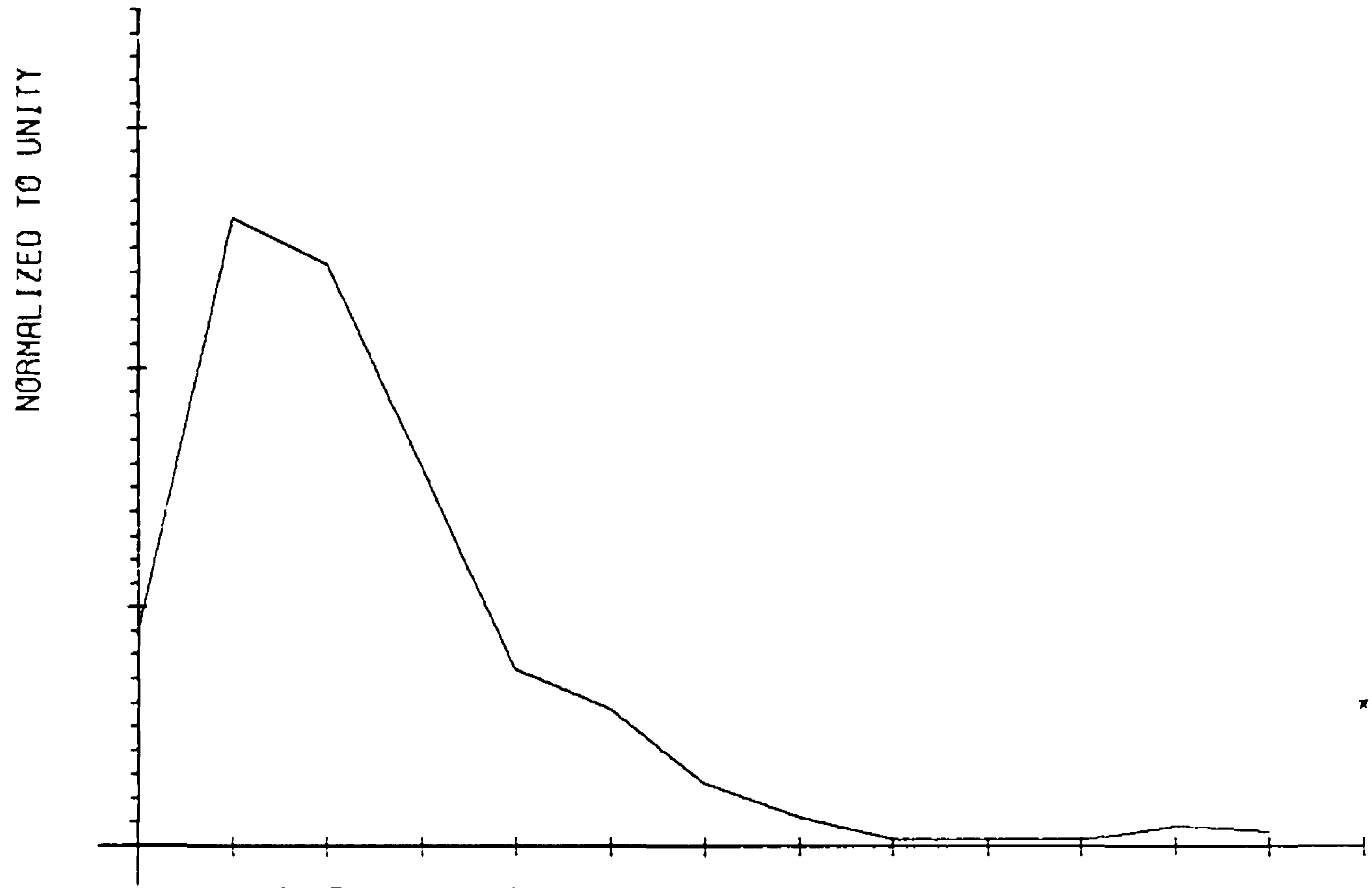

Fig. 7 - Mean Distribution of Velocities for Selected Subjects on a Static Scene (17.40)

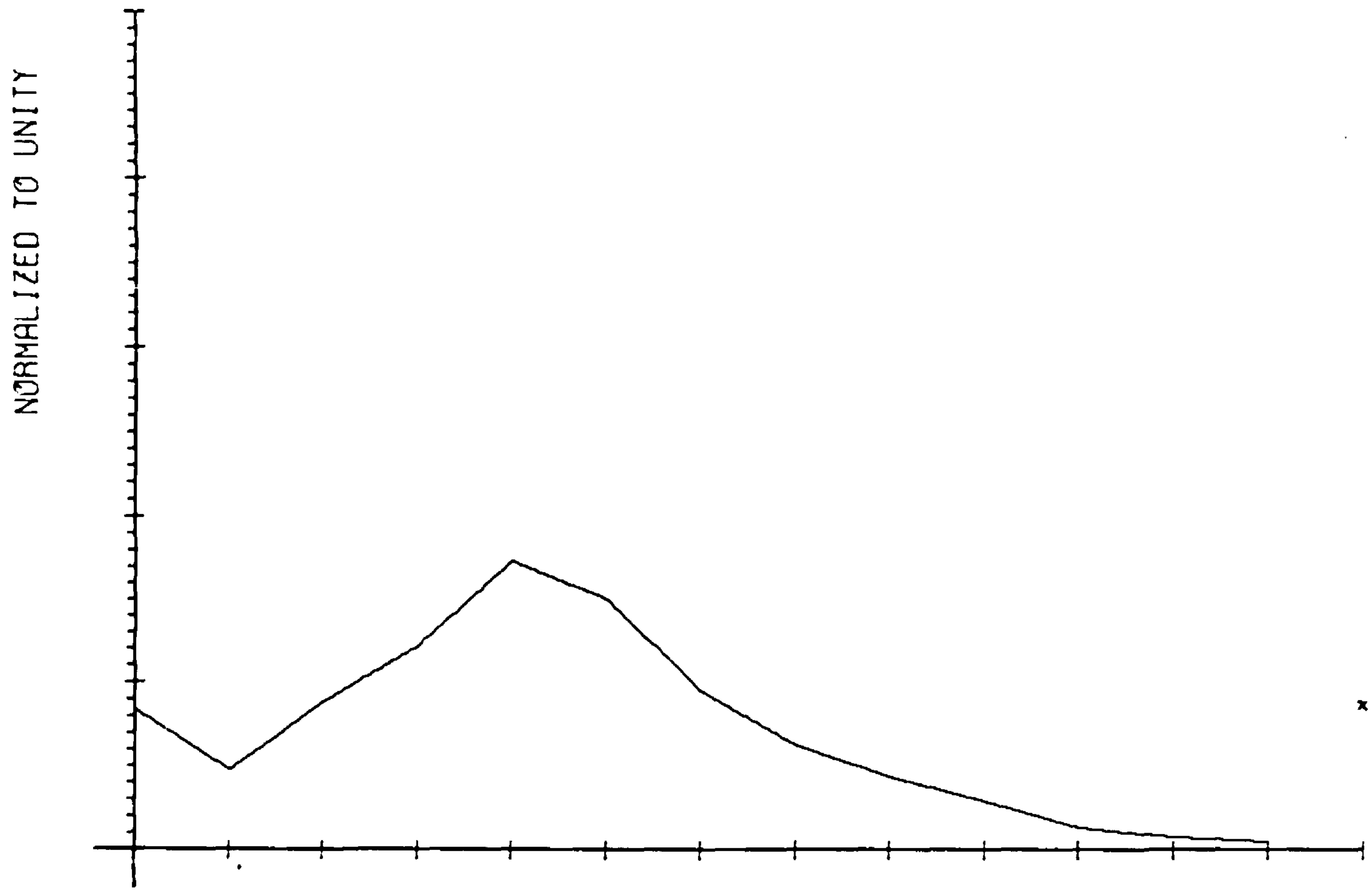

Fig. 8 - Mean Distribution of Velocities for Selected Subjects on a Dynamic Scene (36.34)

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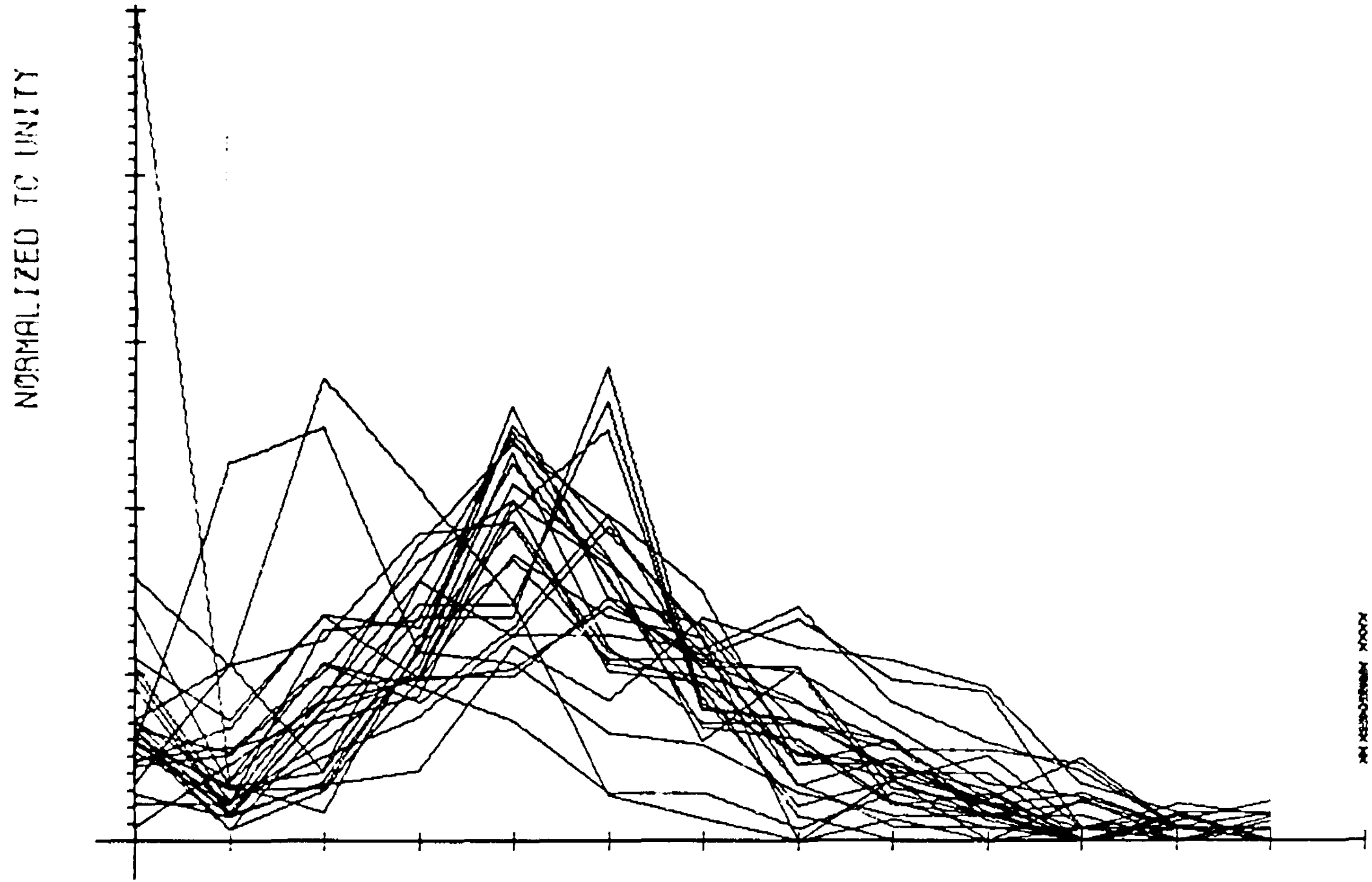

Fig. 9 - Mean Distribution of Velocities for Individual Subjects on a Dynamic Scene (36.34)

Learning scores were obtained from two instruments which had been especially constructed to test the subjects' recall of stimulus films. These tests, called the Visual Recognition and the Visual and Auditory Recall, are described in the Procedures Chapter.

Separate regression analyses were run on each of the four eye-movement indices for both of the learning measures. Thus a total of eight regression analyses were performed. Each analysis had three predictors--one of the learning measures, IQ, and Age--and one criterion, one of the four eye-movement indices.

The results of each regression analysis are reported in Tables VI-XIII. A multiple correlation is given below the tables where the analysis allowed inclusion of at least one predictor variable in the multiple regression equation.

Examination of the results reveals that there is a fairly consistent pattern to the relationship of the variables and the direction of the relationships. Of the eye-movement indices used as the criterion measures, NOMS and MINS are correlated significantly with intelligence over both sets of data with which they were tested. These relationships are negative with NOMS and positive with MINS. Thus IQ appears to be the only one of the three variables which exhibits a fairly high degree of relationship with any of the eye-movement indices. The relationships of the other variables and the criterion measures are such that addition of them as variables in the respective regression equations does not affect prediction of the criteria substantially. Since the R's are not substantially higher than any of the correlations of the individual variables and the eye-movement indices, they can be taken as a degenerate form of a true multiple correlation coefficient which includes the combined relationship of two or more predictors with a criterion measure.

The finding that intelligence is related to NOMS and MINS adds verification to the results from the pilot study. In that study, a high relationship was found between the NOMS and MINS indices and intelligence. Since the sample in this study was restricted to a narrower range of scores, any evidence of a significant relationship between intelligence and these indices is important. It is assumed that had the sample been more heterogeneous, including the lower end of the curve, the correlation would have been much higher. The direction of the relationship between NOMS, MINS, and intelligence, however, is opposite in direction to that found in the pilot study. In the pilot study, NOMS were positively correlated with intelligence and MINS were negatively correlated. A possible explanation might be that the correlations for the pilot study were over only one scene and that scene was static in nature. The scenes over which the data for the correlations were drawn in this study included more dynamic than static scenes. It might be that the direction of the relationship between the eye-movement indices and intelligence changes with the type of scene.

Table VI - Correlations of Predictor Variables with the Eye-Movement Index of NOMS

	Visual Recognition	I.Q.	Age	NOMS
Visual Recognition	1.0000	0.1430	0.0936	0.0405
I.Q.		1.0000	-0.0636	-0.3643
Age			1.0000	-0.0963
NOMS				1.0000

R = 0.364, P < 0.05

Table VII - Correlations of Predictor Variables with the Eye-Movement Index of MINS

	Visual Recognition	I.Q.	Age	MINS
Visual Recognition	1.0000	0.1430	0.0932	-0.0267
I.Q.		1.0000	-0.0636	0.4177*
Age			1.0000	0.1107
MINS				1.0000

*p < 0.05
R = 0.418, p < 0.01

Table VIII - Correlations of Predictor Variables with the Eye-Movement Index of Small Saccades

	Visual Recognition	I.Q.	Age	Small SACS
Visual Recognition	1.0000	0.1430	0.0932	-0.1830
I.Q.		1.0000	-0.0636	-0.0263
Age			1.0000	0.01[illegible]
Small Saccades				1.0000

Table IX - Correlations of Predictor Variables with the Eye-Movement Index of Large Saccades

	Visual Recognition	I.Q.	Age	Large SACS
Visual Recognition	1.0000	0.1430	0.0932	0.1572
I.Q.		1.0000	-0.0636	0.0214
Age			1.0000	-0.0489
Large Saccades				1.0000

Table X - Correlations of Predictor Variables with the Eye-Movement Index of NOMS

	Visual & Auditory Recall	I.Q.	Age	NOMS
Visual & Auditory Recall	1.0000	0.3989*	0.1478	-0.3029
I.Q.		1.0000	-0.0636	-0.3390
Age			1.0000	-0.1113
NOMS				1.0000

*$p < 0.05$
$R = 0.339$, $p < 0.05$

Table XI - Correlations of Predictor Variables with the Eye-Movement Index of MINS

	Visual & Auditory Recall	I.Q.	Age	MINS
Visual & Auditory Recall	1.0000	0.3989*	0.1478	0.2842
I.Q.		1.0000	-0.0636	0.3846
Age			1.0000	0.1510
MINS				1.0000

*$p < 0.05$
$R = 0.395$, $p < 0.05$

Table XII - Correlations of Predictor Variables with the Eye-Movement Index of Small Saccades

	Visual & Auditory Recall	I.Q.	Age	Small SACS
Visual & Auditory Recall	1.0000	0.3989*	0.1478	0.1056
I.Q.		1.0000	-0.0636	-0.0482
Age			1.0000	0.0213
Small Saccades				1.0000

*$p < 0.05$

Table XIII - Correlations of Predictor Variables with the Eye-Movement Index of Large Saccades

	Visual & Auditory Recall	I.Q.	Age	Large SACS
Visual & Auditory Recall	1.0000	0.3989*	0.1478	0.2820
I.Q.		1.0000	-0.0636	0.1595
Age			1.0000	-0.1104
Large Saccades				1.0000

*$p < 0.05$

That no relationship was found between learning and the eye-movement indices adds verification to another result from the pilot study since no relationship was found between any eye-movement index and learning in that study. Further comments on this finding are made in the Discussion of Results section.

Analysis of Scene Variables. One of the purposes of the data analysis was to determine whether certain scene variables influence the eye movements of subjects. For this analysis, scenes were classified on the following: (1) Motion--Static vs Dynamic, (2) Complexity--Simple vs Complex, (3) Novelty--Familiar vs Novel, (4) One Type of Movement--Reversal vs No-Reversal, (5) Clarity--Clear vs Unclear, (6) Number of Attention Centers--Unicenter vs Multicenter, (7) Ambiguity of Meaning--Ambiguous vs Unambiguous, (8) Unity of Elements--Distractive vs Integrative, and (9) Arousal--Tranquil vs Arousal. Most of these variables* were identified in the pilot study and/or other research studies as possibly influencing the eye movements of subjects. In addition, the type of audio used in a few scenes was considered.

After each scene had been classified on the various elements, the scenes were sorted into groups which had the same classification. Comparisons on one of the four types of eye movements were then made between a group of scenes having identical variable classification with another group of scenes having the same classification except for one. For example, one group of scenes might have the classification Static, Simple, Familiar . . . and be compared with a group of scenes having the classification Dynamic, Simple, Familiar . . . . More than one comparison was made on each variable whenever possible. For example, scenes might be the same on different groups of variables except the one of interest such as Static, Complex, Novel . . . and Dynamic, Complex, Novel . . . . In some instances it was possible to have four replications of the sample design because of the number of groupings available, whereas in others only one comparison could be made. A simple analysis of variance model was used to make the comparisons. The data for all 26 subjects were used in each analysis.

In order to determine whether differences in the main analysis resulted from the classification variable rather than from idiosyncrasies of the scenes themselves, a further analysis of variance was applied to each design, with the scenes themselves serving as levels of the independent variable rather than the classification variable itself. An example of a typical design is given in Appendix J.

In presenting the results of the analysis, a specific question will be asked followed by the data to answer that question. A summary table showing the means, mean squares, and F-ratios is given for each design. Also, a summary of the results for all of the questions follows

*A definition for each of these variables may be found in the problem statement.

at the end of this section.

Motion. Question 1: Are there significant differences in subjects' eye-movement indices between scenes which are classified as Dynamic and others classified as Static, all other scene variables held constant?

Four comparisons were made between groups of scenes equated on all other scene characteristics except the variable of motion. Thus the comparison was between scenes that were Static and scenes that were Dynamic. The four eye-movement indices of NOMS, MINS, Small Saccades, and Large Saccades, were the dependent variables in each of the comparisons. Across all four designs the analysis, as summarized in Table XIV, shows significant differences varying from $p < 0.05$ to $p \ll 0.01$ between the Static and Dynamic groups of scenes on five of the comparisons. The significant differences are for MINS on the first design, NOMS and Large Saccades on the third design, and Small Saccades and Large Saccades on the fourth design. Although the rest of the differences do not reach significance, it is relevant to note the direction of the differences and the consistency of the direction. With only one exception--Large Saccades on Design two--Dynamic scenes have fewer NOMS, more MINS, more Small Saccades, and more Large Saccades than Static scenes. In other words, the scenes with moving objects elicit more eye movements than the scenes with stable objects.

An analysis of the scene differences for each design within the groups, tends to support for the most part that the significant differences, where they occur, are due to the categorization of Static vs Dynamic rather than to other characteristics of the scenes themselves.

Complexity. Question 2: Are there significant differences in subjects' eye-movement indices between scenes which are classified as Simple and others classified as Complex, all other scene variables held constant?

There are no significant differences for any of the eye-movement indices on the comparison between Simple and Complex scenes. Thus it appears that the complexity of a scene does not influence the eye-movement indices of a subject. Only one analysis was run since there were no other groupings of scenes on which all the variables except complexity were held constant (Table XV).

Novelty. Question 3: Are there differences in subjects' eye-movement indices between scenes which are classified as Familiar and others classified as Novel, all other scene variables held constant?

Analysis of the eye-movement indices on scenes which were classified as Familiar and scenes which were classified as Novel indicates no significant differences on any of the comparisons for the indices of NOMS, MINS, and Small Saccades. Two of the comparisons do reveal significant

Table XIV - Summary Table: ANOVA on Static vs Dynamic Scenes

Design	1					2				
Index \ Statistic	Means Static	Means Dynamic	Mean Squares	F-Ratio	d.f.	Means Static	Means Dynamic	Mean Squares	F-Ratio	d.f.
1[a]	0.7392	0.7229	0.0033001	1.409	1,26	0.7670	0.7554	0.0018139	< 1	1,26
2	0.1749	0.1991	0.0070270	6.973**	1,26	0.1691	0.1788	0.0012916	< 1	1,26
3	0.0494	0.0518	0.0000812	< 1	1,26	0.0427	0.0460	0.0001467	< 1	1,26
4	0.0253	0.0257	0.0000013	< 1	1,26	0.0210	0.0195	0.0000248	< 1	1,26

Design	3					4				
Index \ Statistic	Means Static	Means Dynamic	Mean Squares	F-Ratio	d.f.	Means Static	Means Dynamic	Mean Squares	F-Ratio	d.f.
1[a]	0.7457	0.7128	0.0146651	5.988**	1,26	0.7674	0.7524	0.0030508	1.412	1,26
2	0.1777	0.1937	0.0034448	2.400	1,26	0.1689	0.1702	0.0000220	< 1	1,26
3	0.0520	0.0524	0.0000028	< 1	1,26	0.0364	0.0450	0.0009865	4.684*	1,26
4	0.0244	0.0411	0.0037317	28.421++	1,26	0.0247	0.0324	0.0004324	5.608*	1,26

*$p < 0.05$

**$p < 0.025$

+$p < 0.01$

++$p << 0.01$

[a] On this and other tables of this nature, Index 1 refers to NOMS, 2 to MINS, 3 to Small Saccades, and 4 to Large Saccades.

Table XV - Summary Table: ANOVA on Simple vs Complex Scenes

Statistic / Index	Means		Mean Squares	F-Ratio	d.f.
	Simple	Complex			
1	0.7108	0.7121	0.0000222	< 1	1,26
2	0.2008	0.2097	0.0000000	< 1	1,26
3	0.0543	0.0507	0.0000000	< 1	1,26
4	0.0311	0.0275	0.0000000	< 1	1,26

differences between Familiar and Novel scenes on Large Saccades. These differences are significant at the 0.025 and 0.01 levels, respectively. In general, the analysis of the individual scenes suggests that the significant differences found are due to the characteristic of Familiar and Novel. Since one difference is caused by the Novel scenes having more Large Saccades and the other from the Novel scenes having fewer Large Saccades; however, no conclusion can be drawn with regard to the influence of this variable on Large Saccades. The influence of this variable on the other eye-movement indices is negligible (Table XVI).

<u>Type of Movement</u>. Question 4: Are there differences in subjects' eye-movement indices between scenes which are classified as Reversal and others classified as No-Reversal, other scene variables held constant?

As defined in the problem statement, Reversal is a type of movement in which the foreground appears to be moving when in actuality the background is moving. No-Reversal is a type of movement in which the foreground <u>is</u> moving. Two analyses provide information with which to answer the question comparing these two types of scenes. A summary of the results is given in Table XVII.

Differences between the Reversal and No-Reversal scenes on NOMS and MINS reach extremely high levels of significance, well beyond the 0.01 probability level for both analyses. The indices of Small Saccades and Large Saccades are significantly different on the first comparison, but not on the second. The significant differences between the two types of scenes indicate that those scenes with the Reversal characteristic

Table XVI - Summary Table: ANOVA on Familiar vs Novel Scenes

Design	1					2					3				
Statistic / Index	Means Familiar	Means Novel	Mean Squares	F-Ratio	d.f.	Means Familiar	Means Novel	Mean Squares	F-Ratio	d.f.	Means Familiar	Means Novel	Mean Squares	F-Ratio	d.f.
1	0.7272	0.7339	0.000[illegible]139	< 1	1,2[illegible]	0.7539	0.7511	0.0001054	< 1	1,2[illegible]	0.7[illegible]70	0.7521	0.003013[illegible]	< 1	1,2[illegible]
2	0.1842	0.1779	0.0005377	< 1	1,2[illegible]	0.1799	0.1785	0.0000241	< 1	1,2[illegible]	0.1[illegible]91	0.1883	0.0049939	1.412	1,2[illegible]
3	0.049[illegible]	0.0485	0.00001[illegible]1	< 1	1,2[illegible]	0.0431	0.0419	0.000019[illegible]	< 1	1,2[illegible]	0.0427	0.0450	0.0000[illegible]7[illegible]	< 1	1,2[illegible]
4	0.0390	0.039[illegible]	0.0000042	< 1	1,2[illegible]	0.0231	0.0284	0.0003750	7.[illegible]53**	1,2[illegible]	0.0210	0.014[illegible]	0.000[illegible]531	8.042+	1,2[illegible]

*$p < 0.05$
**$p < 0.025$
+$p < 0.01$
++$p << 0.01$

Table XVII - Summary Table: ANOVA on Reversal vs No-Reversal Scenes

Design	1					2				
Statistic / Index	Means Reversal	Means No Reversal	Mean Squares	F-Ratio	d.f.	Means Reversal	Means No Reversal	Mean Squares	F-Ratio	d.f.
1	0.4228	0.7529	1.4715033	23[illegible].[illegible]42++	1,2[illegible]	0.[illegible]23	0.7732	0.1[illegible]0340	5[illegible].048++	1,2[illegible]
2	0.4170	0.1725	1.202999	28[illegible].081++	1,2[illegible]	0.2[illegible]43	0.1594	0.1485331	70.9[illegible]0++	1,2[illegible]
3	0.0[illegible]28	0.0454	0.0041239	7.102**	1,2[illegible]	0.0409	0.0314	0.0012165	1.384	1,2[illegible]
4	0.0434	0.0292	0.0027155	10.827+	1,2[illegible]	0.0325	0.03[illegible]0	0.0001584	< 1	1,2[illegible]

*$p < 0.05$
**$p < 0.025$
+$p < 0.01$
++$p << 0.01$

have fewer NOMS, more MINS, more Small Saccades and more Large Saccades than the No-Reversal scenes. The Reversal scenes, therefore, when compared to No-Reversal scenes, receive similar eye-movement responses from subjects to the overall Dynamic scenes when they are compared to Static scenes. That is, the subjects exhibit more eye movements to the Reversal scenes. Since only two scenes were compared in each of the two analyses, no further information is available to check whether the diffe ences obtained are a result of the Reversal and No-Reversal classification or due to other characteristics within the scenes themselves.

<u>Clarity</u>. Question 5: Are there significant differences in subjects' eye-movement indices between scenes which are classified as Clear and others classified as Unclear, all other scene variables held constant?

Inspection of the single analysis comparing eye movements on Clear and Unclear scenes reveals that there are statistically significan differences on both Small Saccades and Large Saccades. The significance is at the 0.05 and well beyond the 0.01 levels, respectively. The scene classified as Unclear receive more Large Saccades while those classified as Clear receive more Small Saccades. It may be that when the scenes are Unclear, the subjects make large eye movements in an attempt to determine what the content of the scene is. Again, since the comparisons were made on only one scene of each category type, it must be assumed that the differences are the result of the scene classification. Result of this analysis are given in Table XVIII.

Table XVIII - Summary Table: ANOVA on Clear vs Unclear Scenes

Statistic / Index	Means		Mean Squares	F-Ratio	d.f.
	Clear	Unclear			
1	0.7644	0.7598	0.0002759	< 1	1,2[illegible]
2	0.1572	0.1478	0.0011816	< 1	1,2[illegible]
3	0.0506	0.0392	0.0017785	4.354*	1,2[illegible]
4	0.0278	0.0532	0.0086868	49.355++	1,2[illegible]

*$p < 0.05$
**$p < 0.025$
+$p < 0.01$
++$p \ll 0.01$

Number of Attention Centers. Question 6: Are there significant differences in subjects' eye-movement indices between scenes which are classified as Unicenter and others classified as Multicenter, all other scene variables held constant?

Two analyses were run to answer this question. The results show differences on MINS in one analysis and differences on Large Saccade in the other. Where the significant differences occur, the Unicenter scenes receive more MIN responses and the Multicenter scenes receive more Large Saccades. That Multicenter scenes receive more Large Saccades is not surprising in view of the fact that a scene having many centers of attention would require the subject to make larger eye movements than a scene having only one center of attention. However, it is surprising that both designs do not elicit the same results. When the scenes within the designs were checked, it was noted that on the second design, the scenes classified as Multicenter often included the model of the airplane from Piloting and Control of an Airplane. Although this object included a number of areas of attention, they were not as widely scattered as the objects in many of the other scenes. This could have been responsible for the difference in the findings for the two designs. A summary of the analyses is given in Table XIX.

Ambiguity of Meaning. Question 7: Are there significant differences in subjects' eye-movement indices between scenes which are classified as Unambiguous and others classified as Ambiguous, all other scene variables held constant?

The data analysis of scenes classified as Unambiguous and scenes classified as Ambiguous shows marked differences between these two type of scenes on NOMS in one analysis ($p < 0.01$) with the comparison almost reaching significance in the other. There is a significant difference on Large Saccades ($p \ll 0.01$) in both analyses. Ambiguous scenes receive more NOMS and fewer Large Saccades. Although the MINS and Small Saccades differences do not reach significance, the direction is for the Ambiguous scenes to have fewer MINS and Small Saccades. Thus it appears that scenes which have more than one possible meaning induce a more fixed type of eye reaction rather than large movement while scenes with only one possible meaning induce larger eye movements. These results are presented in Table XX. That the differences identified are due to the scene classification rather than any other characteristics of the scenes themselves is supported by the individual scene analysis.

Table XIX - Summary Table: ANOVA on Unicenter vs Multicenter Scenes

Design	1					2				
Statistic / Index	Means		Mean Squares	F-Ratio	d.f.	Means		Mean Squares	F-Ratio	d.f.
	Unicenter	Multicenter				Unicenter	Multicenter			
1	0.7392	0.7158	0.0074203	2.066	1,26	0.7229	0.7457	0.0070410	2.994	1,26
2	0.1768	0.1927	0.0034273	1.651	1,26	0.1996	0.1777	0.0034420	5.450*	1,26
3	0.0494	0.0510	0.0000355	< 1	1,26	0.0518	0.0520	0.0000004	< 1	1,26
4	0.0253	0.0404	0.0030736	26.270++	1,26	0.0257	0.0244	0.0000196	< 1	1,26

*p < 0.05
**p < 0.025
+p < 0.01
++p << 0.01

Table XX - Summary Table: ANOVA on Unambiguous vs Ambiguous Scenes

Design	1					2				
Statistic / Index	Means		Mean Squares	F-Ratio	d.f.	Means		Mean Squares	F-Ratio	d.f.
	Unambiguous	Ambiguous				Unambiguous	Ambiguous			
1	0.7339	0.7757	0.0235968	11.527+	1,26	0.7290	0.7644	0.0108686	4.018	1,26
2	0.1779	0.1624	0.0032295	3.180	1,26	0.1602	0.1572	0.0001203	< 1	1,26
3	0.0485	0.0438	0.0003001	< 1	1,26	0.0534	0.0506	0.0001056	< 1	1,26
4	0.0396	0.0177	0.0064682	64.553++	1,26	0.0555	0.0278	0.0103556	66.255++	1,26

+p < 0.01
++p << 0.01

Unity of Elements. Question 8: Are there differences in subjects' eye-movement indices between scenes which are classified as Distractive and others classified as Integrative, other scene variables held constant?

The analysis of variance on this question results in differences in NOMS and MINS (significant at the 0.025 and 0.05 levels, respectively) in the direction of more NOMS and fewer MINS on the scenes classified as Integrative. These scenes also receive fewer Small Saccades and fewer Large Saccades although the differences do not reach significance. Further analysis of the individual scene differences supports the idea that the differences result from the classification variable (Table XXI).

Arousal. Question 9: Are there differences in subjects' eye-movement indices between scenes which are classified as Tranquil and others classified as Arousal, all other scene variables held constant with the exception of that variable entitled Unity of Elements (Distractive vs Integrative)?

For this analysis, it was not possible to control for all other scene variables since no scenes were available with only the desired characteristic differing. Therefore, the added variable may produce a confounding effect. In this respect, the actual scenes compared were classified as Tranquil with Integrative elements and Arousal with Distractive elements. Analysis of the indices for these scenes (Table XXII) shows that differences between Tranquil and Arousal scenes occur only on Small Saccades. The level of significance for this difference is 0.025.

When individual scene differences are analyzed on Small Saccades, the results show that the scene differences are a result of the classification. It is still questionable, however, as to whether the difference in the scenes is manifested from the Tranquil-Arousal categorization or the Distractive-Integrative classification. Because no differences are found on Small Saccades in the Distractive-Integrative comparison with all other variables held constant on the previous analysis, it appears that the difference can be attributed to the Tranquil-Arousal breakdown.

Audio. An additional question was asked to determine whether there are differences in subjects' eye-movement indices between scenes with the same variable classification with different types of auditory cues. In order to answer this question, scenes were classified into those having auditory cues which directed the viewer to a particular part of the screen (called Direct cues) and those having more Indirect auditory cues.

Table XXI - Summary Table: ANOVA on Integrative vs Distractive Scenes

Statistics / Index	Means		Mean Squares	F-Ratio	d.f.
	Distractive	Integrative			
1	0.7121	0.7539	0.0236259	6.577**	1,26
2	0.2097	0.1799	0.0120154	5.264*	1,26
3	0.0507	0.0431	0.0007904	2.177	1,26
4	0.0275	0.0231	0.0002565	1.797	1,26

*$p < 0.05$
**$p < 0.025$

Table XXII - Summary Table: ANOVA on Tranquil vs Arousal Scenes

Statistic / Index	Means		Mean Squares	F-Ratio	d.f.
	Tranquil	Arousal			
1	0.7655	0.7503	0.0031345	1.201	1,26
2	0.1643	0.1691	0.0003130	< 1	1,26
3	0.0318	0.0446	0.0022298	6.001**	1,26
4	0.0362	0.0359	0.0000012	< 1	1,26

**$p < 0.025$

The data analysis reveals that different types of auditory cues have a significant effect only on Large Saccades. In this instance, scene differences are significant well beyond the 0.01 level. Scenes with Direct cues receive more NOMS, although the differences do not reach significance, and fewer Large Saccades. This may have been caused by less need for searching behavior in such scenes. Inspection of the individual scenes within a group reveals that the major differences are in fact from scenes of different auditory types rather than other scene characteristics. The results of this analysis are summarized in Table XXIII.

Table XXIII - Summary Table: ANOVA on Direct vs Indirect Audio Cue Scenes

Statistics / Index	Means		Mean Squares	F-Ratio	d.f.
	Direct	Indirect			
1	0.7447	0.7217	0.0071716	2.307	1,26
2	0.1802	0.1887	0.0009677	< 1	1,26
3	0.0510	0.0455	0.0004023	< 1	1,26
4	0.0240	0.0426	0.0046612	26.804++	1,26

++p << 0.01

Film Differences. A final analysis was conducted to determine if scenes which were identical on the variable classifications but came from different films would elicit different eye-movement responses. Eight distinct analysis of variance tests were run comparing scenes of like classification from different films. As many comparisons as it was possible were made in view of the restriction of number of scenes which could be controlled. All of the comparisons reveal no significant differences on NOMS and MINS (Table XXIV). Film differences do affect the eye-movement indices of Small Saccades and Large Saccades in a few instances. When the significant differences occur, the analysis of variance test to check the scenes within groups reveals the differences are due to characteristics of the films rather than particular scene elements. However, the results for most of the comparisons add substantiation to the finding that the scene variables rather than the films themselves have more effect on the eye-movement indices, particularly on NOMS and MINS.

Table XXIV - Summary Table: ANOVA on Stimulus Films

Design	1					2					3					4				
Index \ Statistic	Means F1*	Means F2	Mean Squares	F-Ratio	d.f.	Means F1	Means F2	Mean Squares	F-Ratio	d.f.	Means F1	Means F2	Mean Squares	F-Ratio	d.f.	Means F1	Means F2	Mean Squares	Ratio	d.f.
1	0.7500	0.7472	0.0039632	< 1	1,26	0.7108	0.7356	0.0083227	2.936	1,26	0.7635	0.7298	0.0153266	2.185	1,26	0.7210	0.7194	0.0000358	< 1	1,26
2	0.1652	0.1679	0.0000965	< 1	1,26	0.2008	0.1883	0.0020919	1.346	1,26	0.1638	0.1904	0.0102755	2.199	1,26	0.1847	0.1906	0.0005017	< 1	1,26
3	0.0459	0.0433	0.0000897	< 1	1,26	0.0543	0.0431	0.0016901	1.905	1,26	0.0420	0.0616	0.0052333	2.814	1,26	0.0357	0.0498	0.0022525	5.198*	1,26
4	0.0194	0.0207	0 0000245	< 1	1,26	0.0311	0.0329	0.0000416	< 1	1,26	0.0317	0.0172	0.0028427	13.867++	1,26	0.0195	0.401	0.0057247	20.101++	1,26

*F1 = the symbol for the particular film from which the scenes for this comparison were taken.

Design	5					6					7					8				
Index \ Statistic	Means F1	Means F4	Mean Squares	F-Ratio	d.f.	Means F1	Means F4	Mean Squares	F-Ratio	d.f.	Means F3	Means F4	Mean Squares	F-Ratio	d.f.	Means F1	Means F4	Mean Squares	F-Ratio	d.f.
1	0.7172	0.7506	0.0150800	2.601	1,26	0.7352	0.7246	0.0015180	< 1	1,26	0.7509	0.7610	0.0013549	< 1	1,26	0.7209	0.7096	0.0017060	< 1	1,26
2	0.1866	0.1695	0.0040283	< 1	1,26	0.1796	0.1720	0.0007767	< 1	1,26	0.1759	0.1496	0.0093589	3.724	1,26	0.1918	0.1914	0.0000023	< 1	1,26
3	0.0525	0.0446	0.0008433	< 1	1,26	0.0438	0.0487	0.0003144	1.676	1,26	0.0448	0.0253	0.0051158	24.074++	1,26	0.0476	0.0550	0.0007820	1.007	1,26
4	0.0437	0.0355	0.0009160	2.670	1,26	0.0211	0.0536	0.0142009	95.629++	1,26	0.0261	0.0271	0.0000145	< 1	1,26	0.0397	0.0424	0.0001022	< 1	1,26

*p < 0.05
++p << 0.01

Summary and Discussion of Results on Eye-Movement Indices. Controlled study of all variables in telelessons and/or motion pictures would be an almost impossible task. For this reason, this study was exploratory in nature to identify those variables which would be the most meaningful for future research. Thus the results should be considered tentative. Those variables identified as having potential importance will need controlled study before any definite conclusions can be drawn. Nevertheless, the results do add meaningful data to the present knowledge not only of variables important in the study of television and motion pictures but also to the knowledge of eye movements themselves.

The first part of the analysis of eye-movement indices was to determine what types of eye movements subjects use in viewing dynamic bi-dimensional fields such as educational television and motion pictures. In the pilot study, the eye movements observed did not correspond to the dichotomy of fixations and saccades usually reported by educational researchers. Rather, the data fell into a continuum of movements including No Observable Movements, Minimovements, Slides, and Saccades. One purpose of the present study was to verify the existence of this continuum of movement.

Movements quite similar to those observed in the pilot study were identified. These data also fall into a continuum of velocities rather than the extremes of fixations and saccades. These movements were termed No Observable Movements (NOMS), Minimovements (MINS), Small Saccades, and Large Saccades. The analysis of the data was conducted using these four indices.

Another major purpose of the study was to determine whether subject characteristics such as age and intelligence and various stimulus characteristics, i.e., type of film and scene variables, influence the eye-movement indices. In addition, a study was made of the relationship of the subjects' recall of the stimulus films and the eye movements they display. The first analysis was a three-factor analysis of variance including age, intelligence, and films as the independent variables and each of the four eye-movement indices of NOMS, MINS, Small Saccades, and Large Saccades as the dependent variables. The results of these analyses showed only one significant main effect which was for Large Saccades on Films. Since the two films which differ the most on this index are Weather and Water, it is probable that the variable of motion influenced the finding. Weather is a slow-paced film in which only a few elements move at a time. In contrast, Water is an extremely dynamic film many scenes of which have moving objects. Since Water has more Large Saccades, this may mean that the subjects made more large excursion types of movements to follow the larger number of moving objects. The fact that this analysis was conducted over the entire stimulus may be the reason for no other significant results. A washout effect may have occurred because of the length of the stimulus. The remaining analyses were conducted using eye movements over shorter segments of data.

The next analysis was a multiple correlational analysis using two learning tests called Visual Recognition and Visual and Auditory Recall, along with age and intelligence, as the predictor variables and the four eye-movement indices separately as the criterion variables. A fairly consistent pattern of relationships emerged from this analysis. It was found that intelligence is significantly related to both NOMS and MINS. In the case of NOMS the relationship is negative and in the case of MINS the relationship is positive. This finding verifies the result from the pilot study that intelligence is significantly related to the eye movements the subjects exhibit. However, the direction of the relationship is opposite to that found in the pilot study. Data for the correlations in the pilot study were derived from a single scene and that scene was static. Numerous scenes, most of which were dynamic, were analyzed in this study. Thus the difference in type of scene (i.e., whether it was Static or Dynamic) may have caused the difference in the direction of the correlations.*

The correlations of NOMS, MINS and intelligence in the pilot study were also much higher. Of necessity, the subject sample for the present research was restricted in range of IQ scores since children with Low IQs have quite often dropped out of school by the junior high school level. The sample for the correlational analysis was in the average and above-average range. For this reason, it is assumed that if subjects with lower IQ scores had been included in the sample, the correlations would have been much higher. That a significant correlation is found at all, therefore, is quite meaningful.

Learning and age are not found to be significantly related to the eye-movement indices. This adds verification to the finding in the pilot study that learning is not related to eye movements. The project staff had suspected that the learning instrument constructed for the pilot study may have been responsible for the negative results in that study. As a result, they constructed two instruments for this study in which the visual content of the stimulus and the visual and auditory content combined were incorporated. Even with this effort, the findings are negative. It is possible that the measurement instruments for learning are still inadequate in spite of fairly high reliabilities (r--0.80 and 0.84). On the other hand, it is entirely possible that the recall of the subject after the experimental session is finished has little or nothing to do with the eye movements he exhibits at the time the session is taking place. Future studies might consider the relationship between immediate recall on the stimulus and the eye movements for that stimulus. Computer-assisted instruction would offer a convenient means for studying this relationship. A few recent studies in the area of clinical psychology have indicated that the thinking of the subject may influence the eye-movement patterns. For example, in one study** when the subjects were

*Dynamic scenes elicit fewer NOMS and more MINS.

**John S. Antrobus, Judith S. Antrobus, and Jerome L. Singer, "Eye Movements Accompanying Daydreaming, Visual Imagery, and Thought Suppression," J. Abnormal and Soc. Psy., 69:3 (1964), 244-252.

asked to imagine and then to suppress, the differences in the number of some types of eye movements reached significance. Eye-movement studies in education which attempt to clarify how thinking patterns are related to the eye-movement indices might be quite revealing. Controlled studies in which specific directions are given to the subject requiring him to perform various mental tasks, ranging from the simplest up to problem solving, might give researchers an insight into eye-movement indices. This would be helpful in future work on children's thinking.

In the analysis of scene variables, all of the scenes were classified with regard to motion, complexity, novelty, clarity, number of attention centers, ambiguity of meaning, unity of elements, and arousal characteristics. In addition, the type of audio used in a few scenes was considered.

The comparisons show that the motion in a scene has a definite influence on the eye-movement indices of the subjects. Scenes classified as Dynamic have fewer No Observable Movements, more Minimovements, more Small Saccades, and more Large Saccades than Static scenes. In other words, the scenes with movement elicit more eye movements from the subjects. This indicates that as objects in the scene move, it becomes necessary for the subjects to move their eyes more to follow the objects. A similar pattern of eye-movement indices is found on the Reversal scenes. Reversal is a type of movement in which the background moves instead of the foreground. This variable serves essentially the same function as the Dynamic variable in that it takes more eye movements of the subject to follow the Reversal type of movement than it does for him to follow the No-Reversal movement in which the foreground objects are moving.

Variables which do not affect the eye-movement indices are Complexity and Novelty. This may appear surprising since a few researchers have recently reported that these two elements did have an effect on eye movements in their studies. It should be noted that those researchers were reporting the influence of Complexity and Novelty on <u>where</u> the subjects look not <u>how</u> they look. A report on the influence of these variables on <u>where</u> the subjects look is given in the next section of this chapter.

Comparisons of scenes classified as Clear-Unclear, Unicenter-Multicenter, Unambiguous-Ambiguous, and Direct Auditory Cues-Indirect Auditory Cues, also show significant differences in the eye movement indices. The classifications of Unclear, Multicenter with widely-spread objects, Unambiguous and Indirect Auditory Cues elicit more Large Saccades than scenes with classifications of Clear, Unicenter, Ambiguous and Direct Auditory Cues. Significantly more Small Saccades occur on scenes with classifications of Clear and Arousal than those classified as Unclear and Tranquil. Integrative scenes have more NOMS and MINS than do Distractive scenes.

Thus various scene variables do influence the eye movements. Variables which have an effect on all four eye-movement indices are the categories of Dynamic--Static and Reversal--No-Reversal. Further study is needed to determine the exact function of the eye movements in relation to the identified stimulus variables. Research to determine the differences in function of Small Saccades vs Large Saccades and NOMS vs MINS should also prove fruitful.

Descriptive Analysis

Data reported here were analyzed to determine where the subjects look and for what proportion of time. Computer programs were written to print out the data in terms of the number of frames of eye markers falling on each of the points of the field. These data were called the density data. In addition, a computer program was written to give a type of topographical map--a cluster analysis--of the subjects' viewing patterns for a particular scene. Since the eye marker data first appeared without being overlaid on the objects in the scene, a clear view of the eye-movement patterns of the subjects on different scenes was available. The first question was whether the placement of objects in a scene affects the viewing pattern. It was quite obvious merely from inspecting the printouts across scenes that the placement of the objects did affect the pattern. A typical example of the differences occurring across scenes appears in the following printouts. On the first scene of a sequence, 26.10 (Fig. 10), the right side of the screen is filled with objects while the left side of the field is blank. The particular group of subjects whose data appear in this printout look almost exclusively at the filled side of the screen. On the second scene in the sequence, 26.20 (Fig. 11), in which objects fill both sides of the field, these same subjects show quite a different pattern of viewing. These printouts are representative of the various printouts in that they show how the placement of the objects in a scene changes the pattern of viewing. Although the printouts from the cluster analysis were used initially to check such pattern differences, the density analysis was found to be more helpful for descriptive purposes since numerical data were available. Thus these data were used for the remainder of the descriptive analysis.

Density Analysis. In order to answer the questions relative to what elements of a film influence the eye movements of subjects and what types of objects attract the subjects' attention, the computer printouts with the density of eye marker data were analyzed. Replicas of the particular scenes to be analyzed, in terms of the objects within the scene, were carefully plotted over the respective printouts to determine where the eye markers fall relative to these objects. In the density analysis, the areas with the highest number of frames of subjects' eye markers and the stimulus objects falling in those areas were considered. Proportions of eye markers falling on the objects of interest were compared in an attempt to answer pertinent questions of the study.

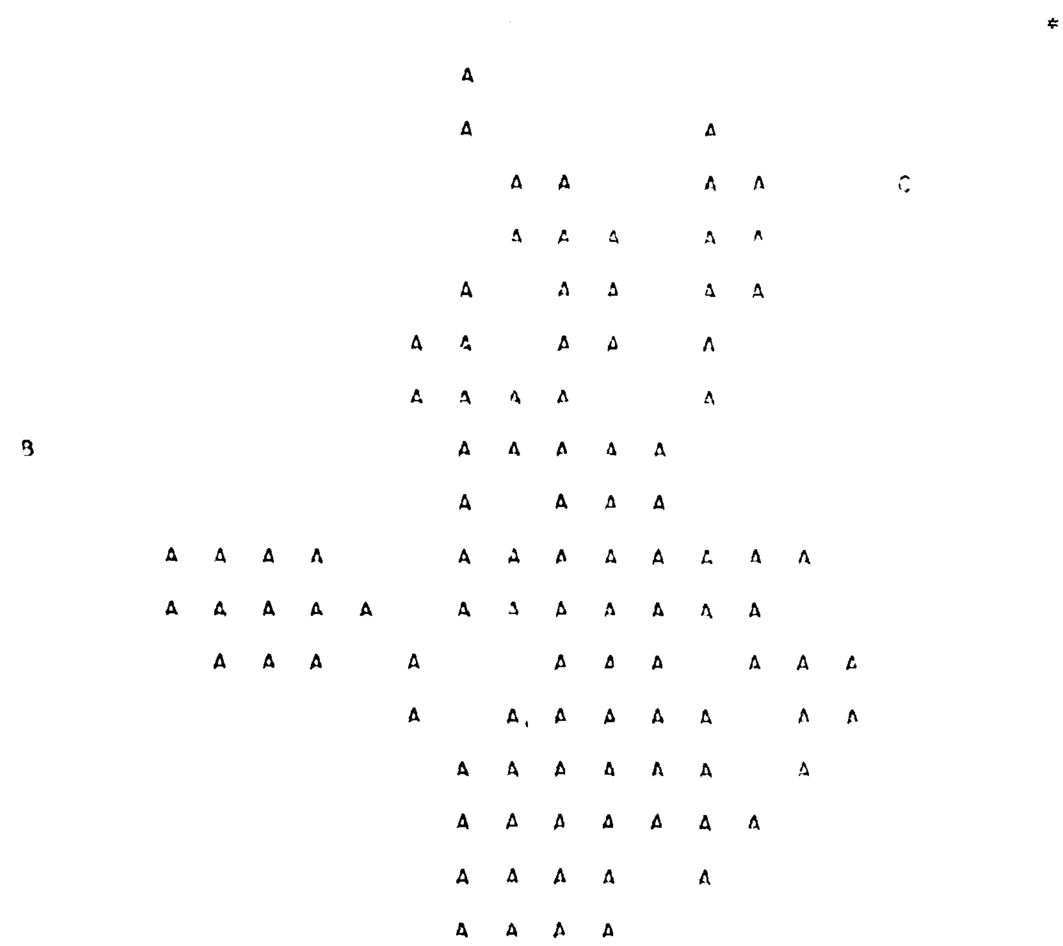

Fig. 10 - Clusters 26.10 High Age Split Screen, Right Filled

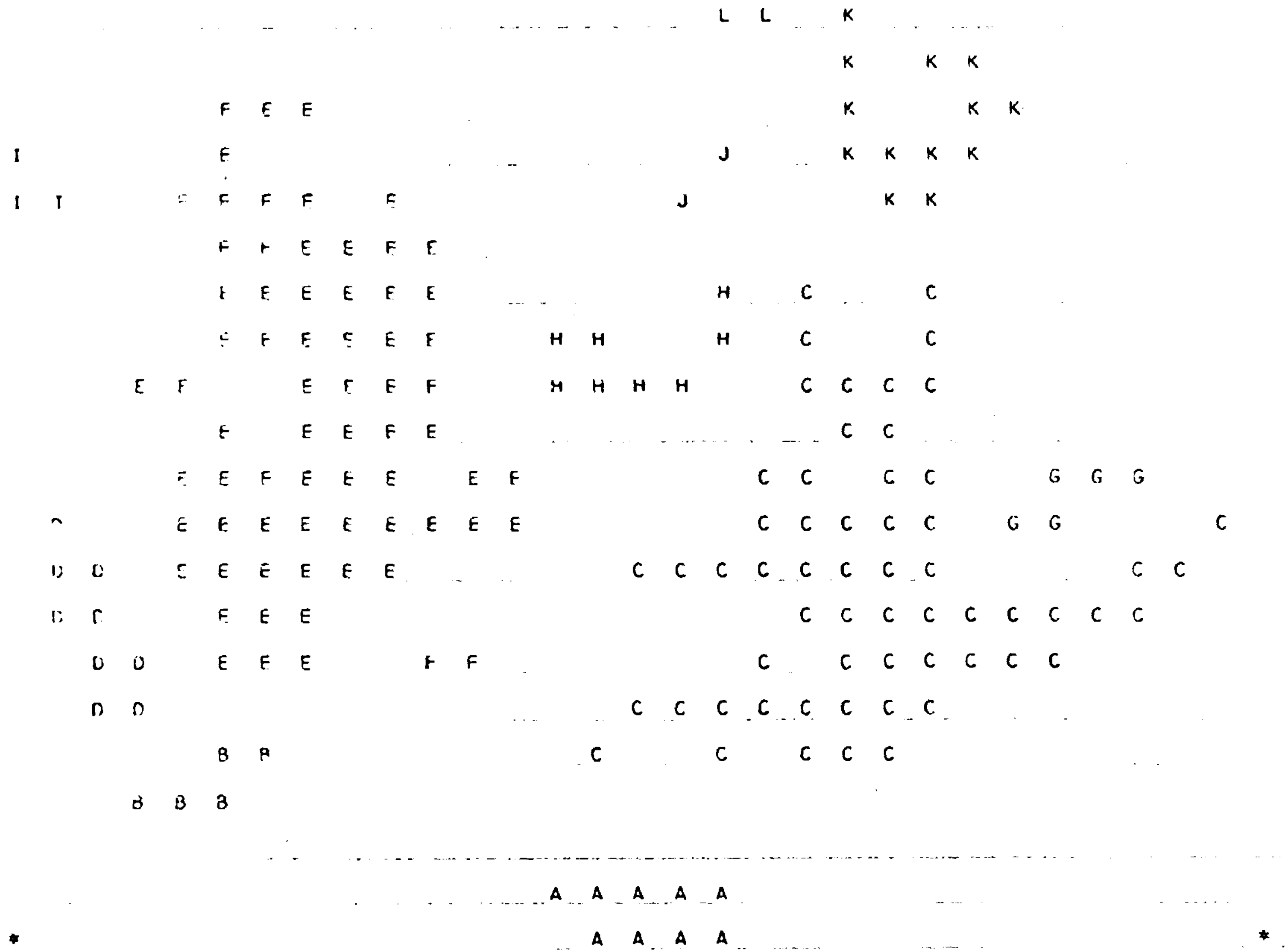

Fig. 11 - Clusters 26.20 High Age Split Screen, Left-Right Filled

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The purpose of this analysis was to determine if certain variables such as novelty of the objects, type and number of objects, movement within the scene, auditory and visual cues, and replication of a scene influence where the subjects look. In presenting the results of the analysis, a specific question of the study will be stated, followed by the data to answer that question. A summary of the results of the density analysis is presented at the end of this section.

Novelty. Question 1: When a series of scenes appear in which one new element is added to an otherwise unchanged scene, will the subjects concentrate more heavily on the new element than other portions of the scene? Will there be IQ and age differences with respect to this viewing pattern?

A series of five scenes (Scenes 2.3 - 2.8) from the award-winning film Weather were used to answer this question. A complete description of the visual and auditory portions of all scenes appears in the scenario in Appendix G. On the first scene in the sequence, a picture of the Earth surrounded by its atmosphere appears. The subjects concentrate on the center of the Earth almost exclusively as 91% of all subjects' eye markers fall in that area. Of the 9% remaining, 8% of the markers are on an area outlined by the atmosphere.

In the next scene where the first new element appears--rays reaching the atmosphere--the subjects change their emphasis and 50% of the concentration is now on the new element of rays while only 36% of the eye markers are still on the Earth. The atmosphere receives the third highest concentration with 13% of the eye markers falling in that area.

On the third scene with the second new element--rays penetrating the atmosphere--50% of the eye markers are on the new element, 29% are still on the rays from the preceding scene, and only 20% of the eye-markers are concentrated on the Earth.

The next scene adds still another new element--rays are now reflected from clouds. Again, the new element of clouds receives the most attention with a density in that area of 46%. The middle of the atmosphere without clouds receives the second highest density of markers with 30%, and the Earth receives the third highest with 22%.

The last scene in the sequence contains numerous elements including the Earth, rays to the atmosphere, rays penetrating the atmosphere, rays reflected from clouds, and a new element, rays reflected from the Earth. This element receives only 20% of the concentration. Other higher areas include the Earth with 29% and the middle of the atmosphere with 21%. Clouds also receives attention with 15%.

A possible explanation for the change in the viewing pattern of the subjects in this last scene may have been that there are now too

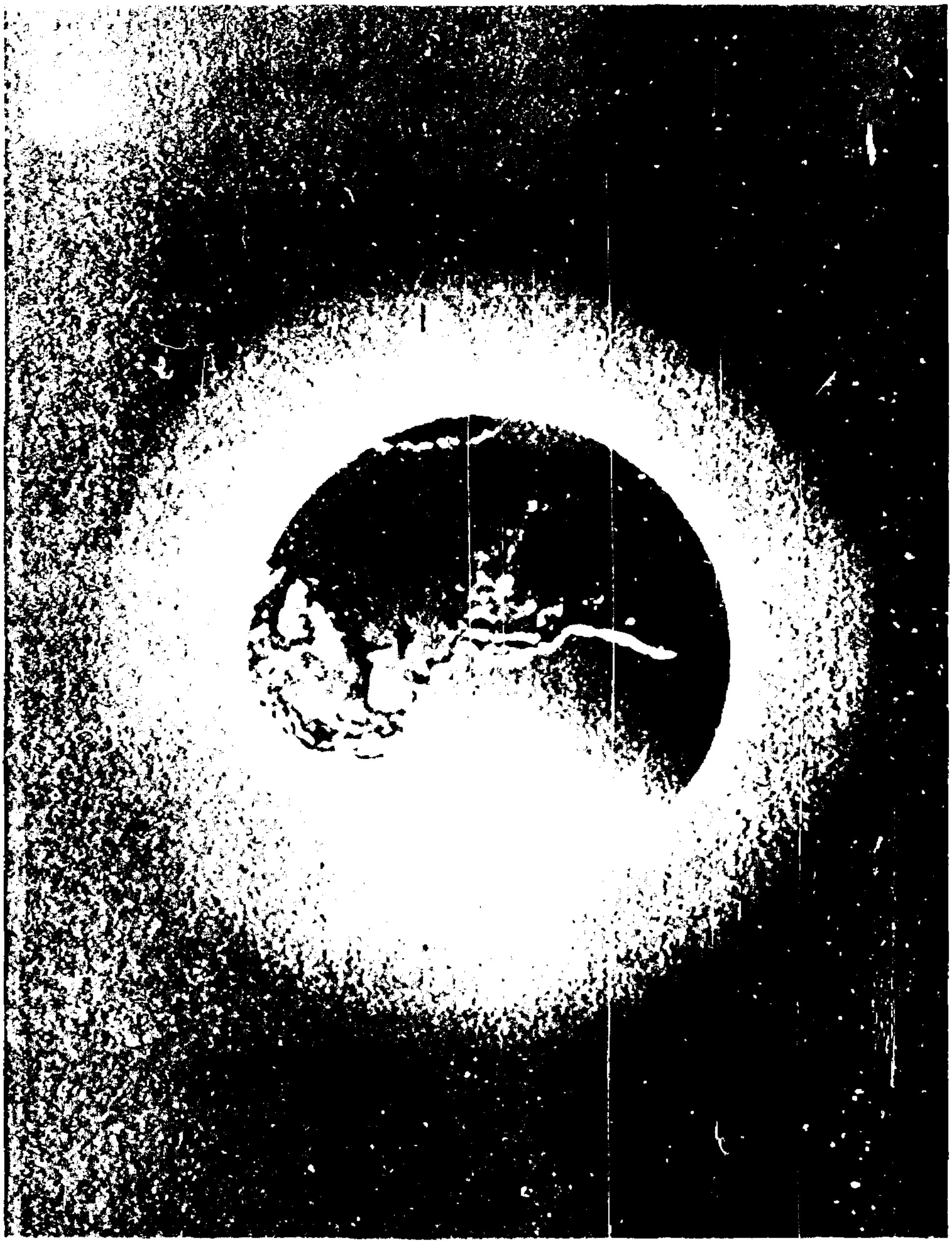


Fig. 12a - Scene 2.3 Earth with Atmosphere

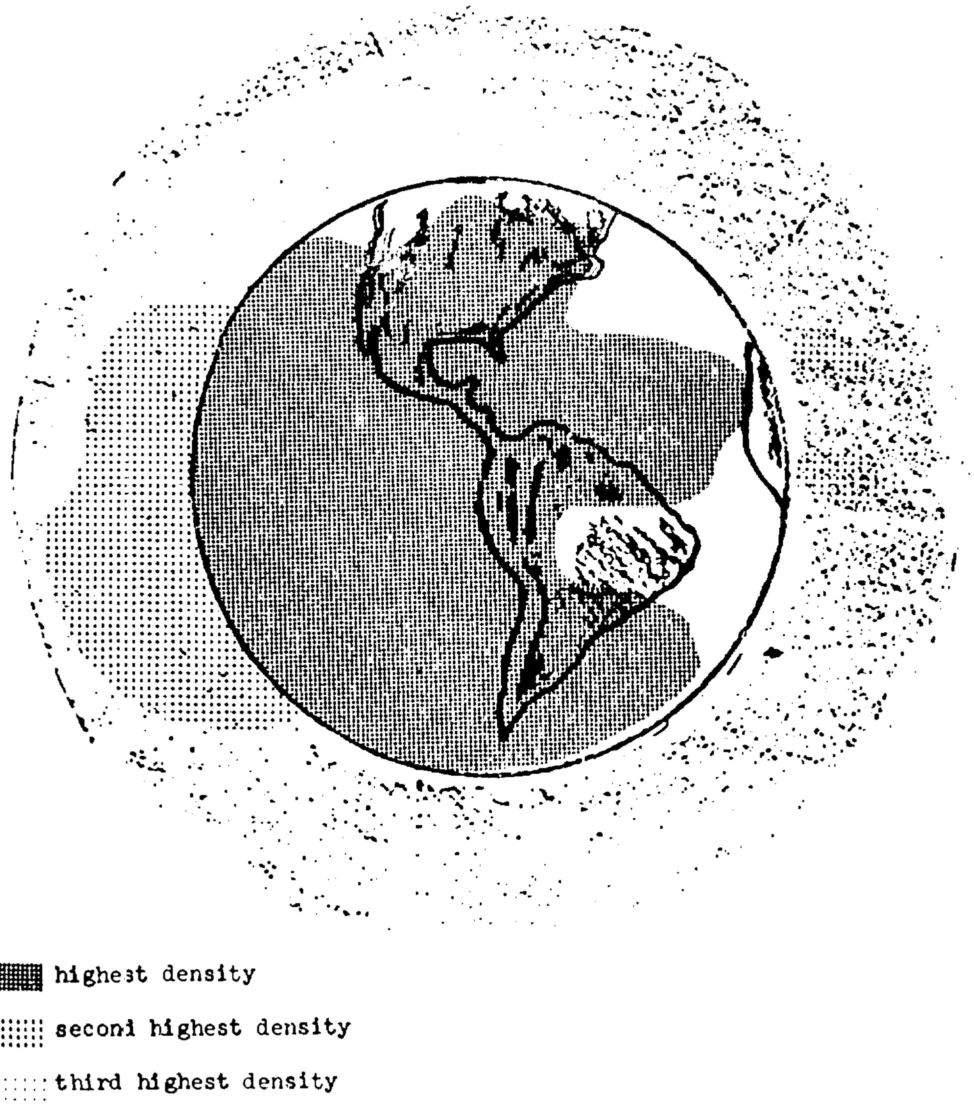


Fig. 12b - Density for all Subjects on Scene 2.3

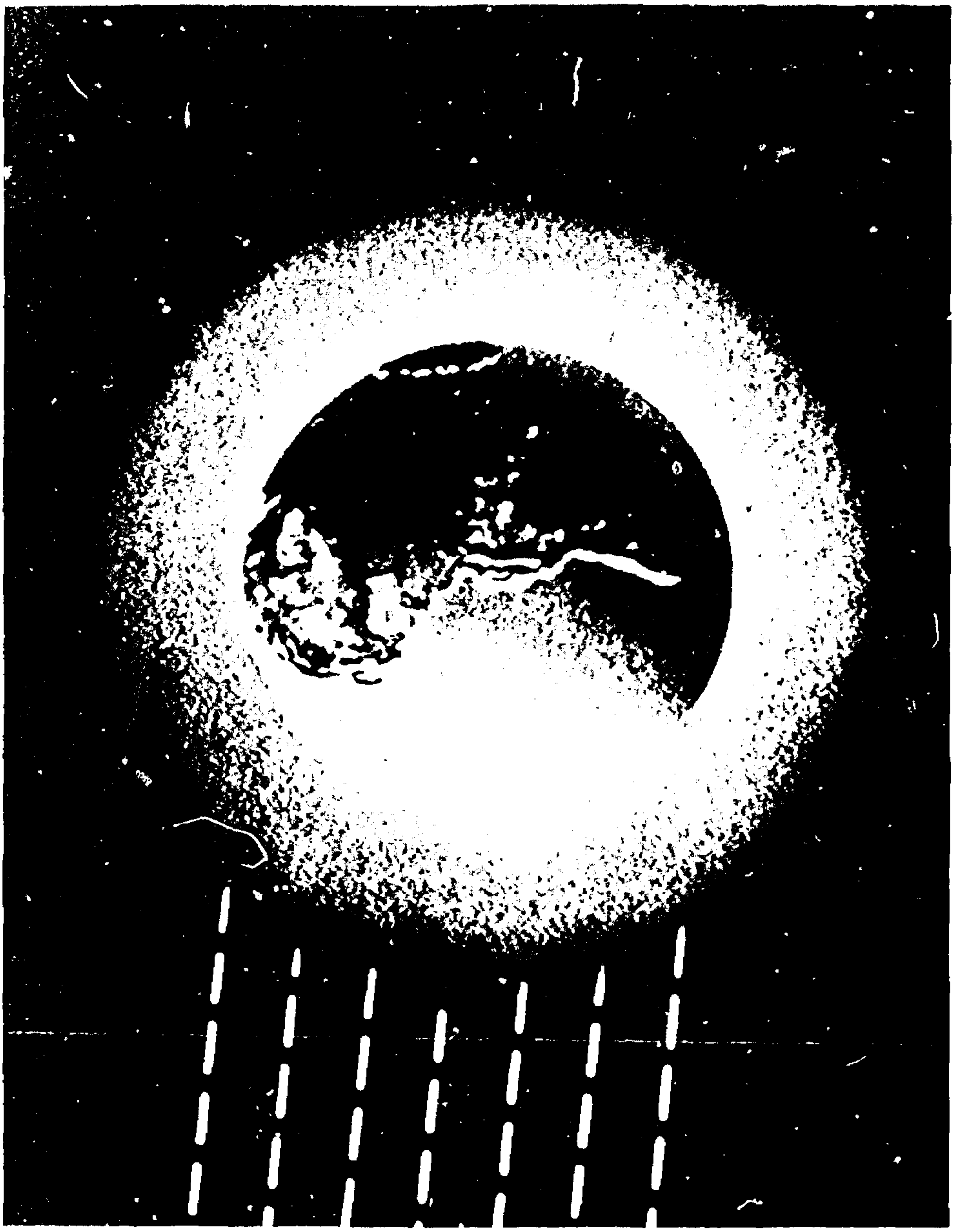


Fig. 13a - Scene 2.4 Rays and Earth

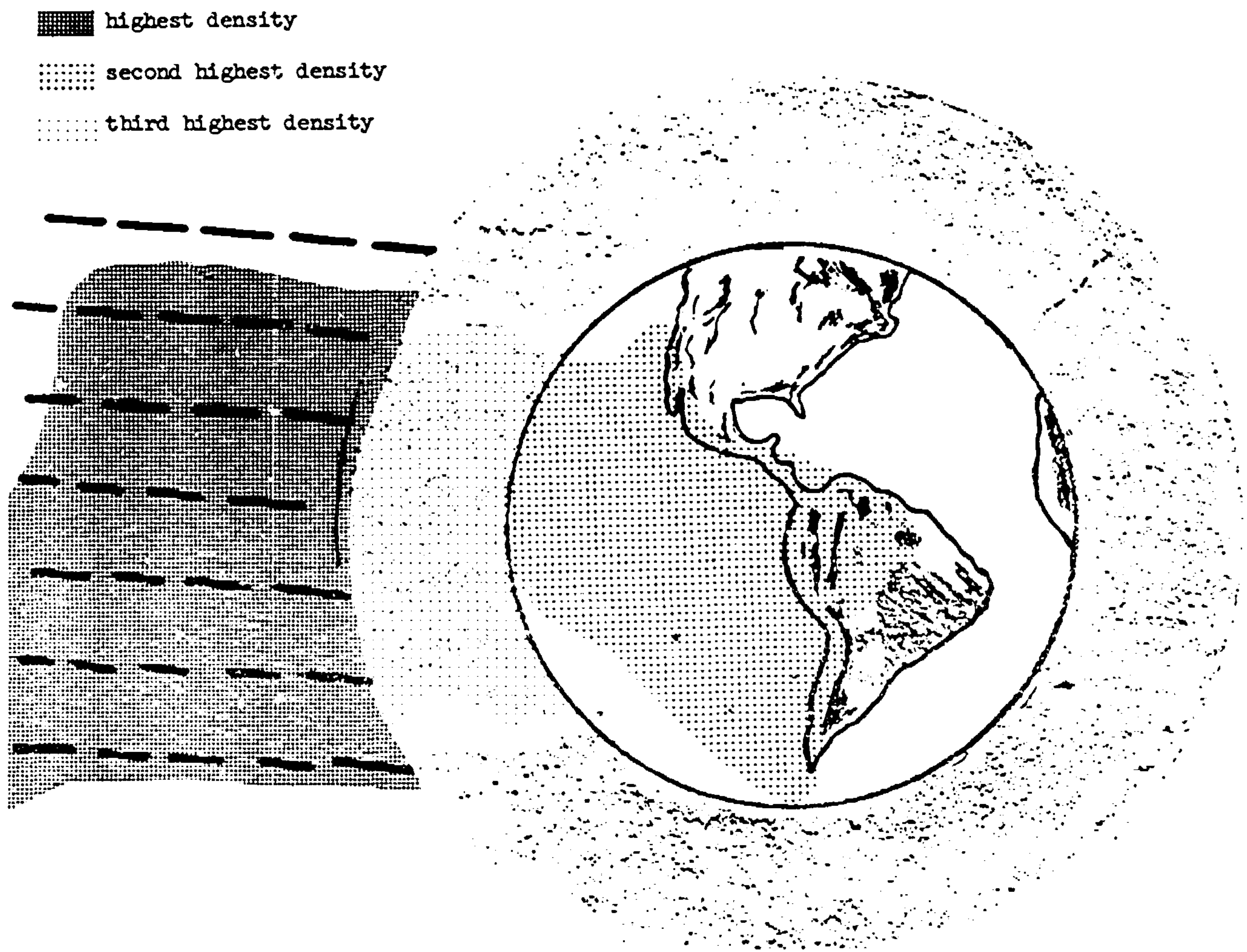


Fig. 13b - Density for all Subjects on Scene 2.4

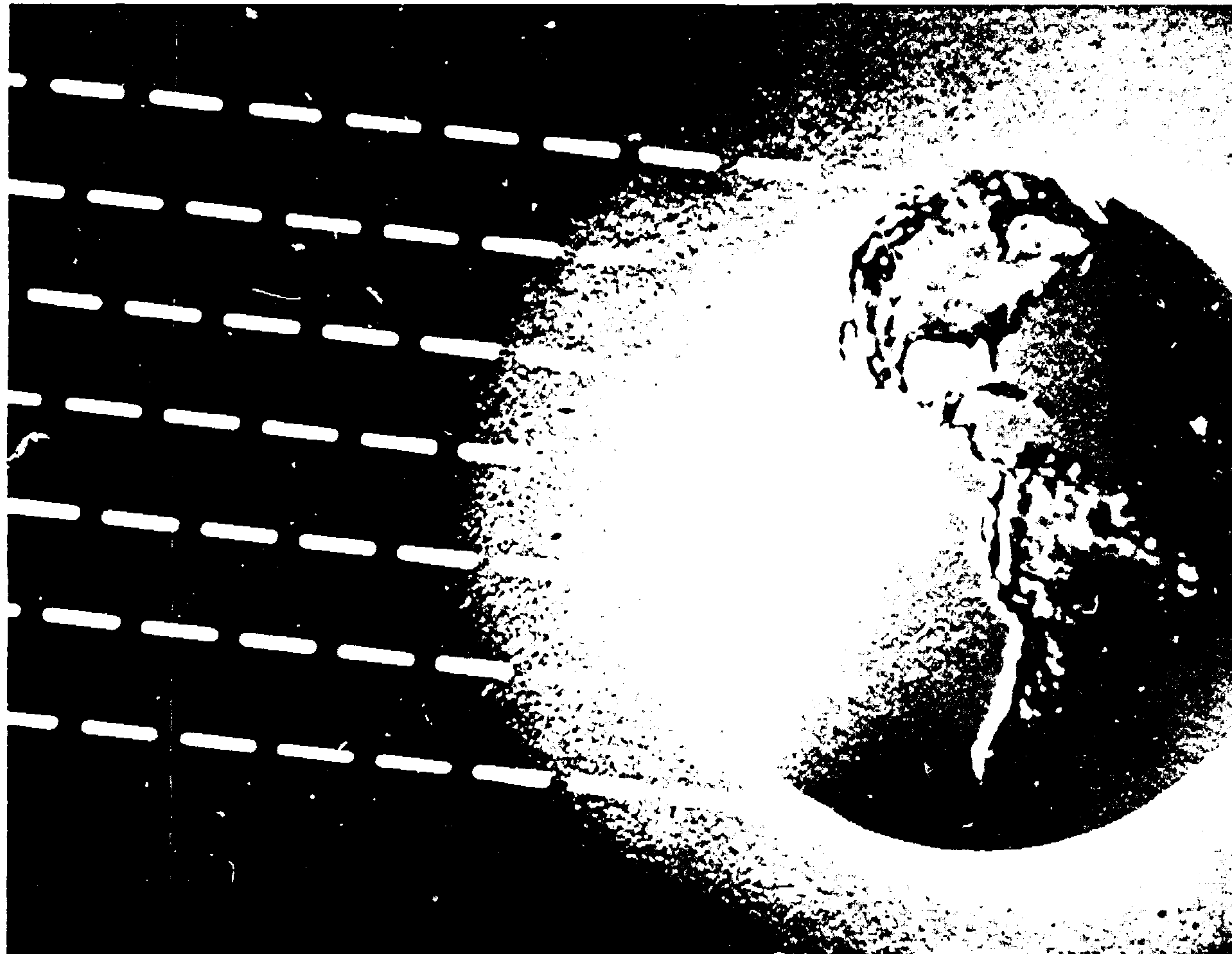


Fig. 14a - Scene 2.6 Rays Penetrating the Atmosphere

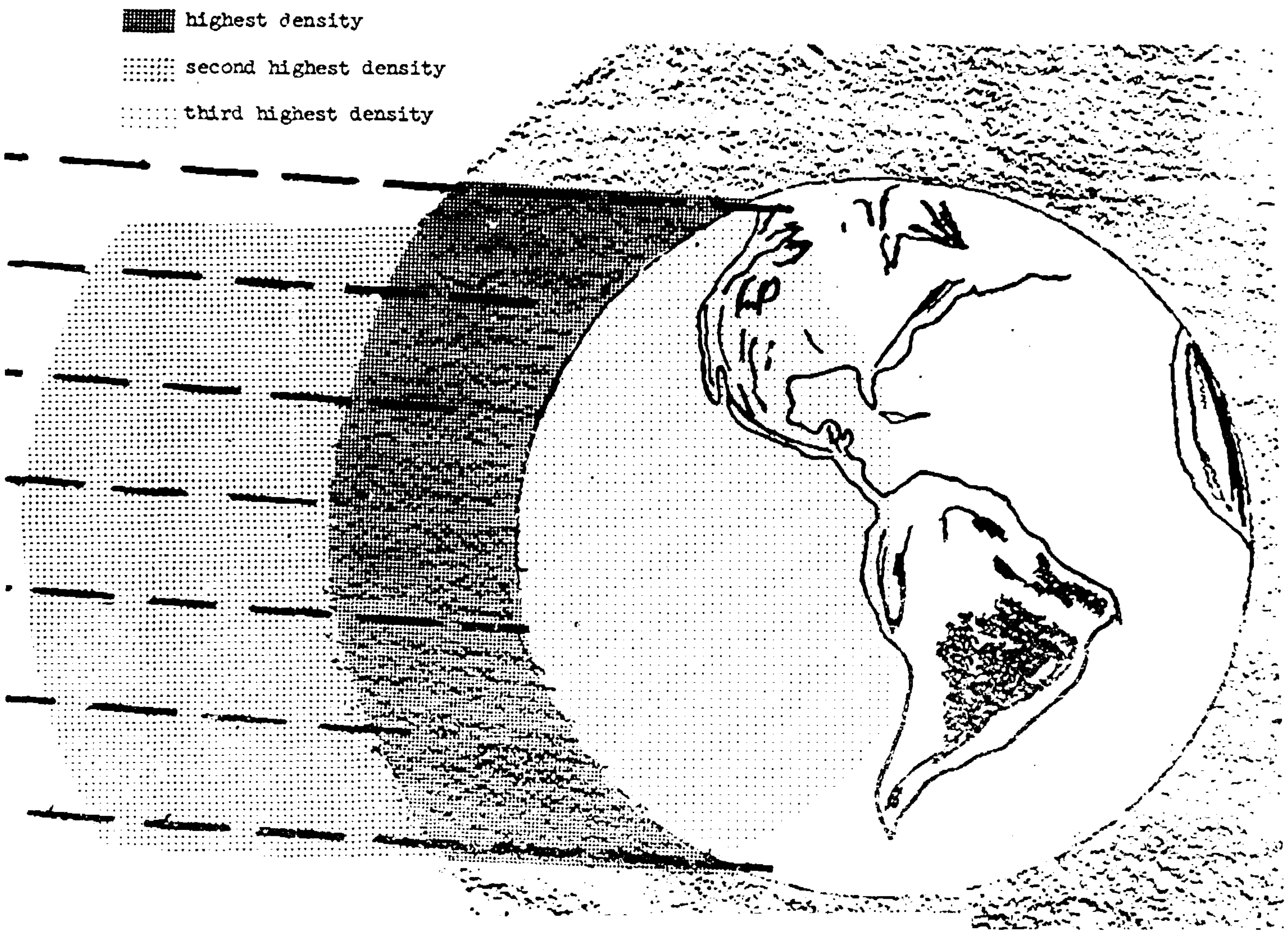


Fig. 14b - Density for all Subjects on Scene 2.6

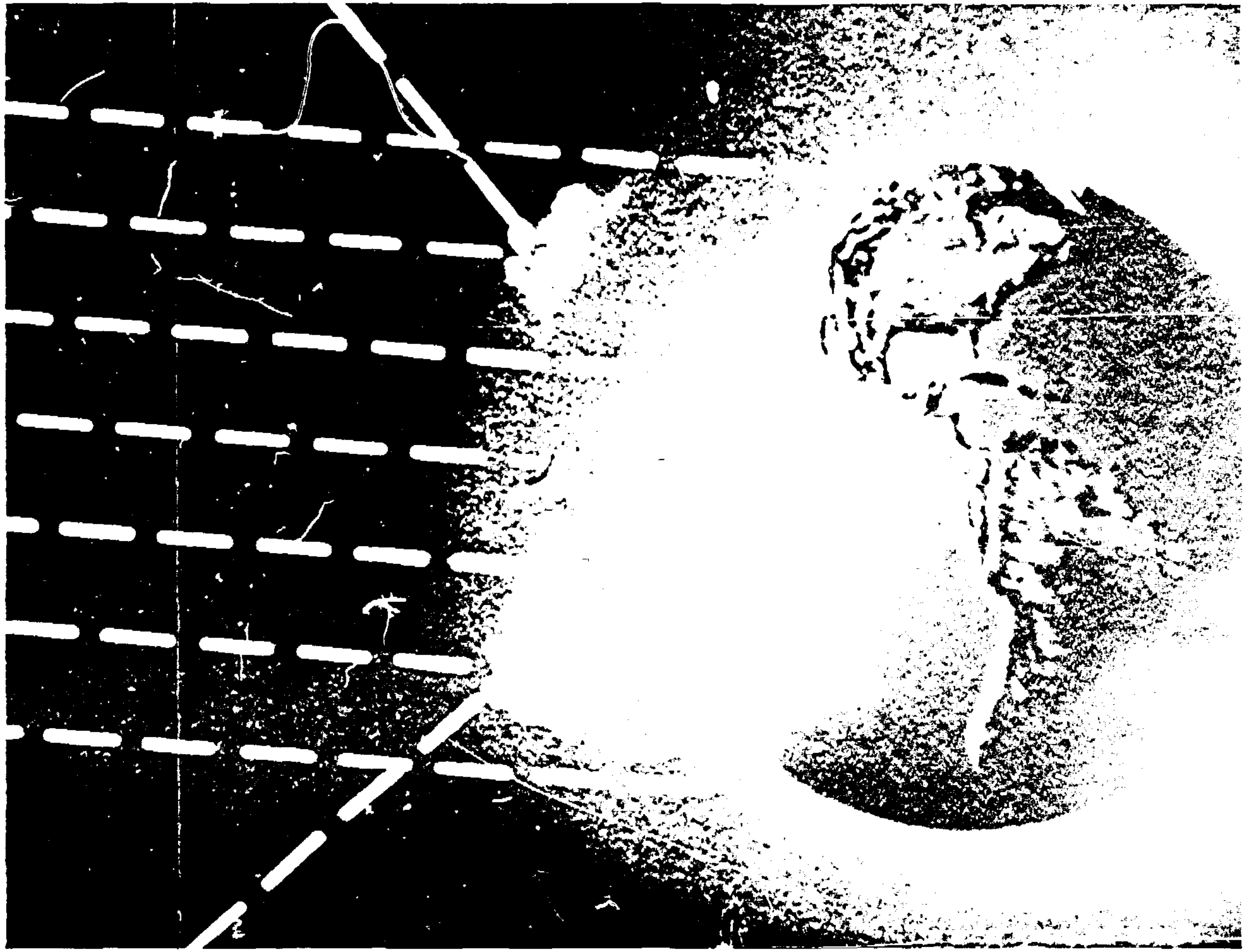


Fig. 15a - Scene 2.7 Rays Reflected from Clouds

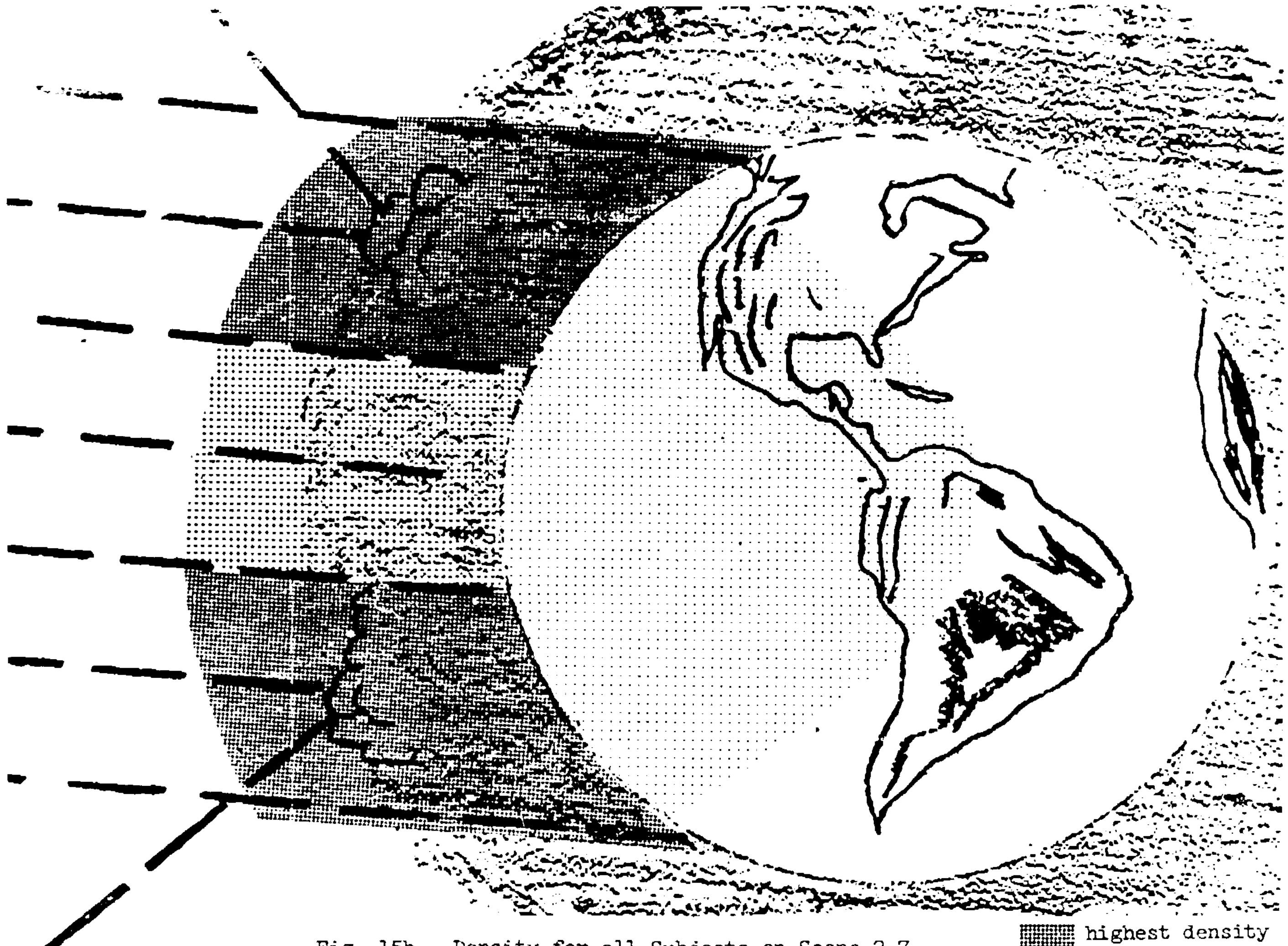


Fig. 15b - Density for all Subjects on Scene 2.7

highest density

second highest density

third highest density

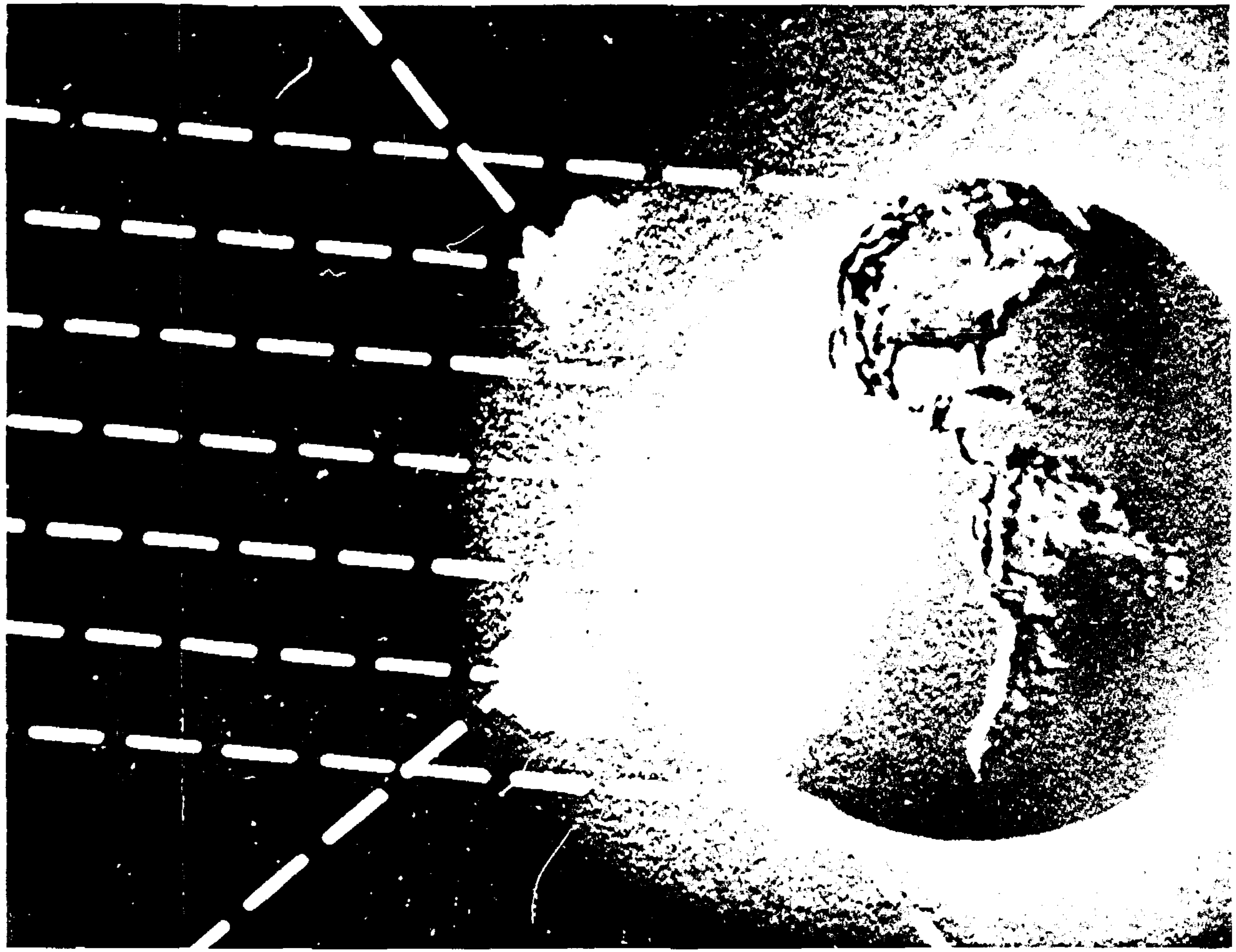


Fig. 16a - Scene 2.8 Rays Reflected from the Earth

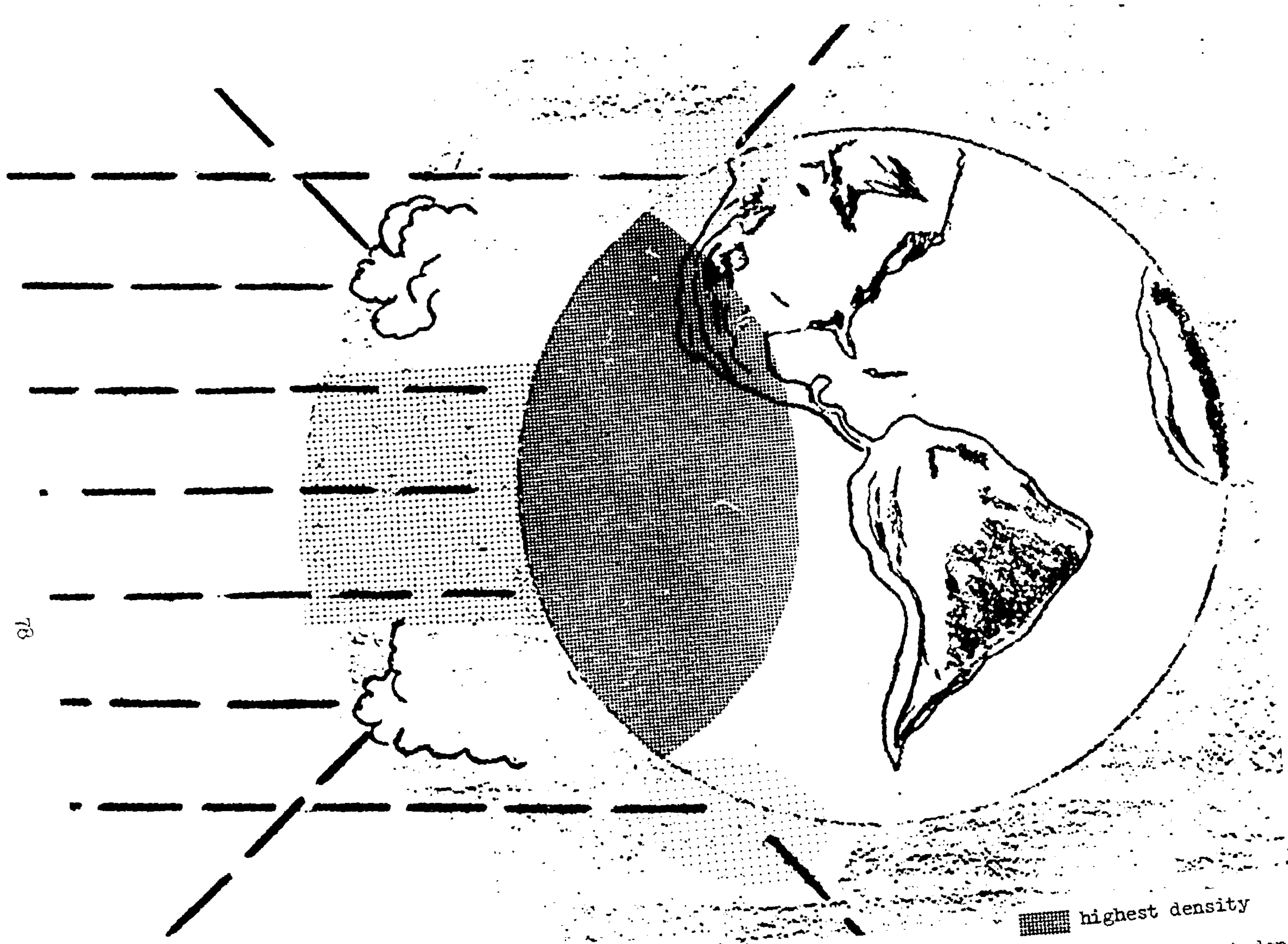


Fig. 16b - Density for all Subjects on Scene 2.8

many elements in the scene to attract the attention of the subjects to the new area. The scene may be too "busy" visually and thus the subjects are distracted from the major visual point. It should be noted, however, that the variable of novelty, in terms of a new element added to each scene, appears to attract the majority of the eye markers in all of the preceding scenes in the sequence.

The data for this sequence were next analyzed in order to determine if there are any age and/or IQ differences in the viewing patterns for these scenes. In general, the viewing patterns of High IQ vs Low IQ subjects and High Age vs Low Age subjects do not differ substantially. For the most part, Low Age subjects seem to concentrate slightly more on the new elements than do the High Age subjects. It may be that the Low Age subjects take longer to identify the new element. On the whole, the proportions of eye marker concentrations for the subgroups are comparable to those of the entire sample. A summary of the proportions for all subjects, as well as the IQ and age comparisons, is presented in Table XXV.

Type of Object. Question 2: On scenes in which a narrator appears, will the subjects look at the narrator's face more than all of the other visual areas of the scene? When there are varying degrees of manipulation of an object by the narrator, will the subjects still look at the narrator's face a large portion of the time? With reference to these questions, will there be differences in the viewing pattern according to the intelligence level of the subjects?

In the pilot study, the stimulus was heavily saturated with narrator scenes. This question was derived from that study where the subjects concentrated on the narrator's face often to the exclusion of demonstration items.

Several scenes in which a narrator appears, from the film Piloting and Control of an Airplane, were analyzed to determine if a similar viewing pattern occurs in this study. In these scenes, the narrator manipulates a model airplane on a stand to varying degrees. He manipulates the plane only a small amount in a few scenes while in other scenes he manipulates the plane a great deal. The question was concerned with whether the subjects, grouped according to intelligence, would look at the narrator's face more than at any other object in the scene. A typical scene where little manipulation is taking place is given in Fig. 17.

Generally speaking, regardless of intelligence, the subjects look very little at the narrator's face. This occurs for scenes in which there is little or no object manipulation and scenes in which there are varying degrees of object manipulation. Subjects appear more interested in aspects of the plane. The density analysis does show,

Table XXV - Proportions of All Subjects (N=26) Eye Markers Falling on Visual Areas of Scenes 2.3, 2.4, 2.6, 2.7, 2.8

	Scene 2.3			Scene 2.4				Scene 2.6				Scene 2.7				Scene 2.8				
	Earth	Atmos.	Other	Earth	Atmos.	Rays	Other	Earth	Original Rays	Rays Through Atmos.	Other	Earth	Mid Atmos.	Rays Off Clouds	Other	Earth	Rays Off Earth	Mid Atmos.	Rays Off Clouds	Other
All Subjects	0.907	0.081	0.012	0.364	0.133	0.501	0.002	0.199	0.285	0.502	0.012	0.223	0.297	0.455	0.023	0.293	0.200	0.208	0.150	0.146
High IQ	0.875	0.125	0.000	0.307	0.190	0.501	0.002	0.241	0.314	0.445	0.000	0.233	0.318	0.369	0.077	0.387	0.203	0.264	0.138	0.005
Low IQ	0.943	0.056	0.001	0.542	0.065	0.392	0.001	0.193	0.183	0.621	0.002	0.238	0.256	0.490	0.016	0.328	0.187	0.149	0.330	0.004
High Age	0.884	0.116	0.000	0.317	0.085	0.598	0.000	0.289	0.227	0.483	0.001	0.258	0.384	0.341	0.014	0.467	0.169	0.223	0.139	0.000
Middle Age	0.967	0.033	0.000	0.577	0.092	0.320	0.001	0.184	0.300	0.514	0.002	0.105	0.221	0.624	0.049	0.141	0.091	0.286	0.475	0.005
Low Age	0.907	0.091	0.002	0.207	0.243	0.550	0.000	0.182	0.318	0.499	0.001	0.316	0.328	0.353	0.003	0.351	0.288	0.240	0.120	0.001

Fig. 17 - Narrator Without Eye Markers

however, that in all of the scenes subjects tend to look at a general area directly below the narrator's face a great portion of the time. This area includes the narrator's tie which is dark against a white background. This area is located between the face and the plane. In Scene 15.30 where the narrator is demonstrating with his hand and a pencil, the subjects look more at that area than any other area of the scene although the tie and torso still receive a great deal of attention. The results for four of the narrator scenes are presented in Table XXVI. Further comments on these responses may be found in the discussion at the end of this section.

Table XXVI - Proportions of Eye Markers Falling on Visual Areas of Scenes 10.10, 13.01, 13.02, 15.30 Narrator Scenes

Scenes	Face	Tie and Torso	Plane	Other
Little or No Object Manipulation				
10.10				
High IQ	0.105	0.628	0.102	0.162
Low IQ	0.081	0.630	0.111	0.177
13.01				
High IQ	0.126	0.357	0.434	0.081
Low IQ	0.164	0.108	0.564	0.164
Varying Degrees of Object Manipulation				
13.02				
High IQ	0.000	0.102	0.710	0.185
Low IQ	0.046	0.148	0.627	0.177
15.30				
High IQ	0.160	0.360	0.023	0.453*
Low IQ	0.116	0.333	0.009	0.539*

*Includes hands moving pencil to demonstrate.

Type of Object. Question 3: On two scenes where, in the first, there is a split screen with information on one side of the screen and an empty space on the other side, will subjects look more at the filled space than at the unfilled space? In the second scene where the blank space is now filled, but the information in the other half remains the same, will subjects look more at the newly-filled area? In reference to the above questions, will there be differences in the viewing patterns of subjects of different age and intelligence levels?

Subjects' responses were analyzed to the simplest type of field possible, a blank space, versus a more complex field with objects. Regardless of age or IQ, subjects look predominantly at the filled side of the screen on the first scene. The density of the IQ groups is shown in Figs. 18b and 18c. On the second scene, where both sides of the screen are filled with objects, there are few differences in the viewing patterns of the respective age groups. All three groups spend roughly half of their time looking at each side of the split screen, although the Middle and Low Age subjects spend slightly more time still looking at the originally-filled side while the High Age subjects spend more time on the newly-filled area.

In contrast, when IQ groups are compared, marked differences occur. The High IQ group looks more at the newly-filled side than does the Low IQ group. The Low IQ subjects look almost equally at both sides of the split screen although they spend slightly more time still looking at the originally-filled side. The comparison of IQ groups is shown in Figs. 19b and 19c. Proportions of eye markers falling in these areas for all of the different groups on the two scenes are given in Table XXVII.

A possible reason for the difference in IQ groups on the second scene may be that the right side of the first scene, 26.10, is fairly complex since it has various objects appearing in it. The scene is also brief as it lasts for only four seconds; Scene 26.20 also lasts for a short time, five seconds. Low IQ subjects may have had more difficulty than the High IQ group in comprehending fully the stimuli in the initially half-filled screen before the other half of the screen was filled.

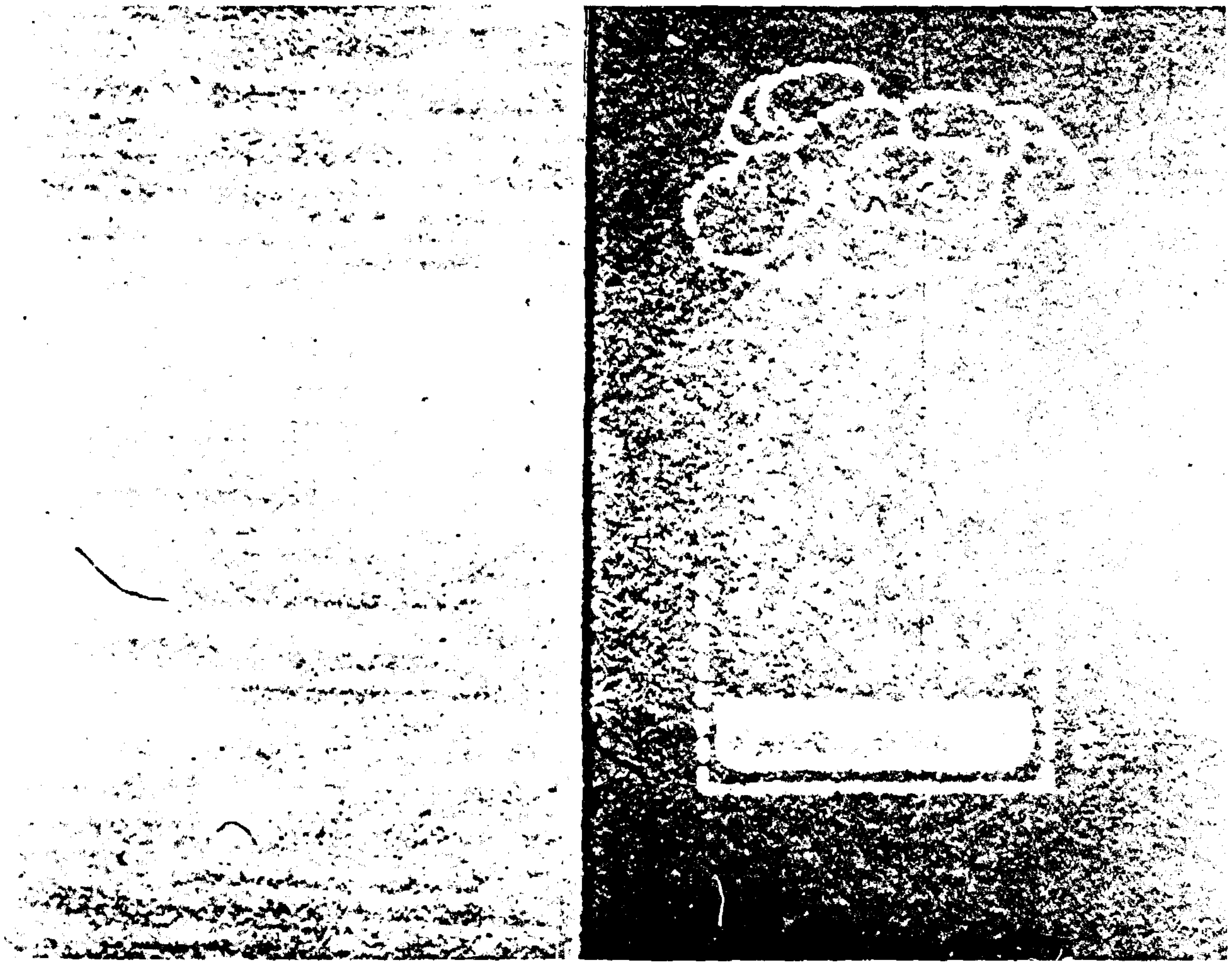
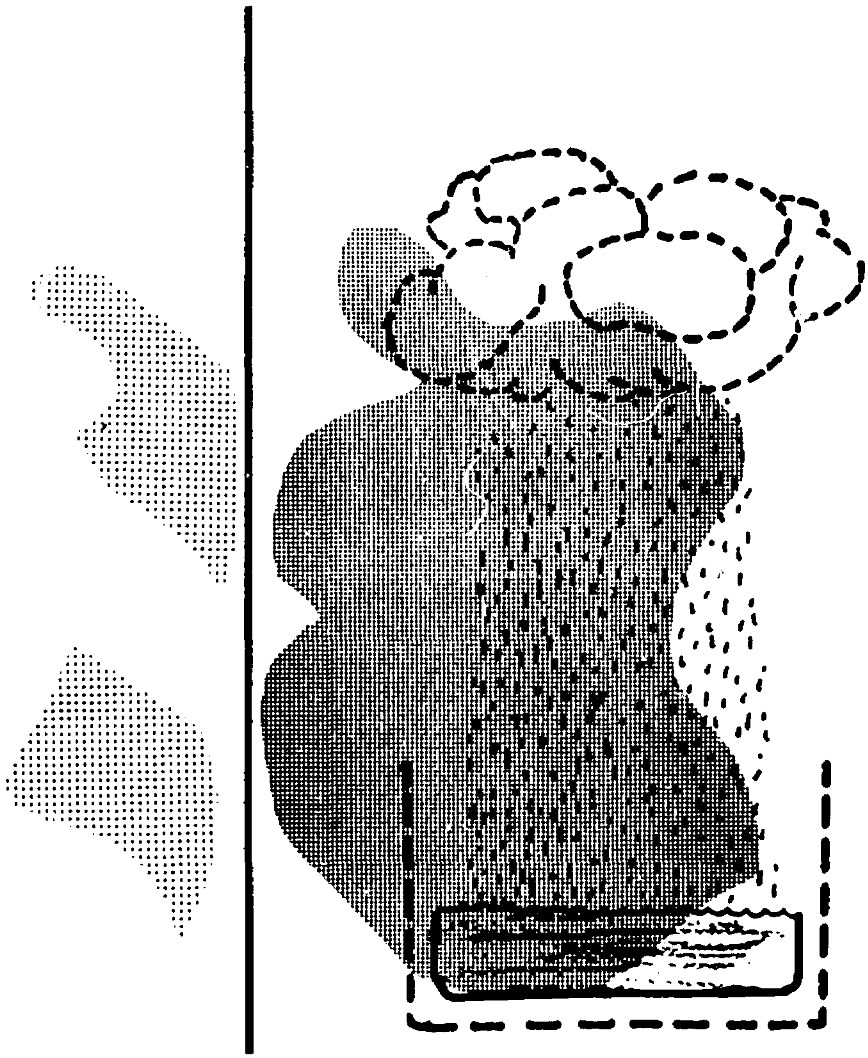


Fig. 1[illegible] - Scene 2.10 Split Screen, Right Filled

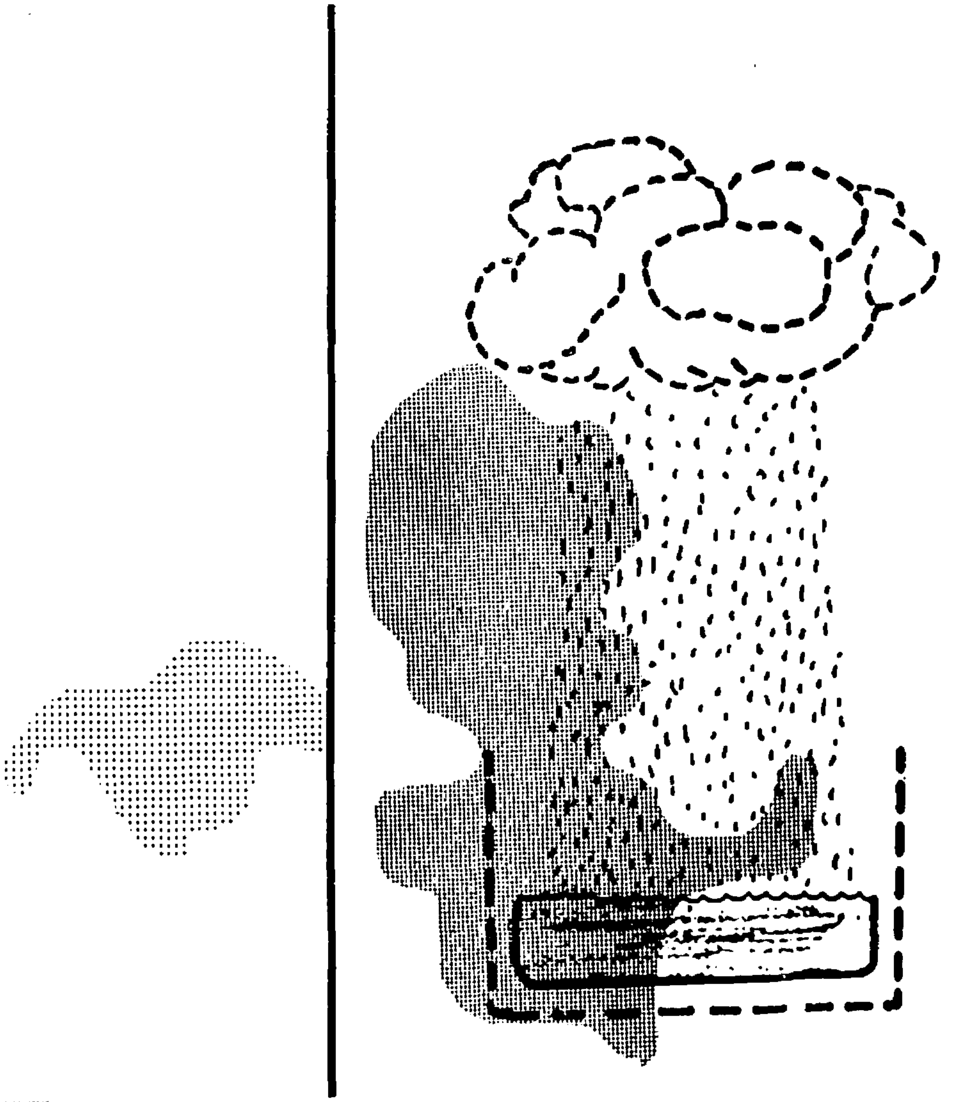


highest density

second highest density

third highest density

Fig. 18b - Density for High I.Q. Subjects on Scene 26.10



highest density

second highest density

third highest density

Fig. 18c - Density for Low I.Q. Subjects on Scene 26.10

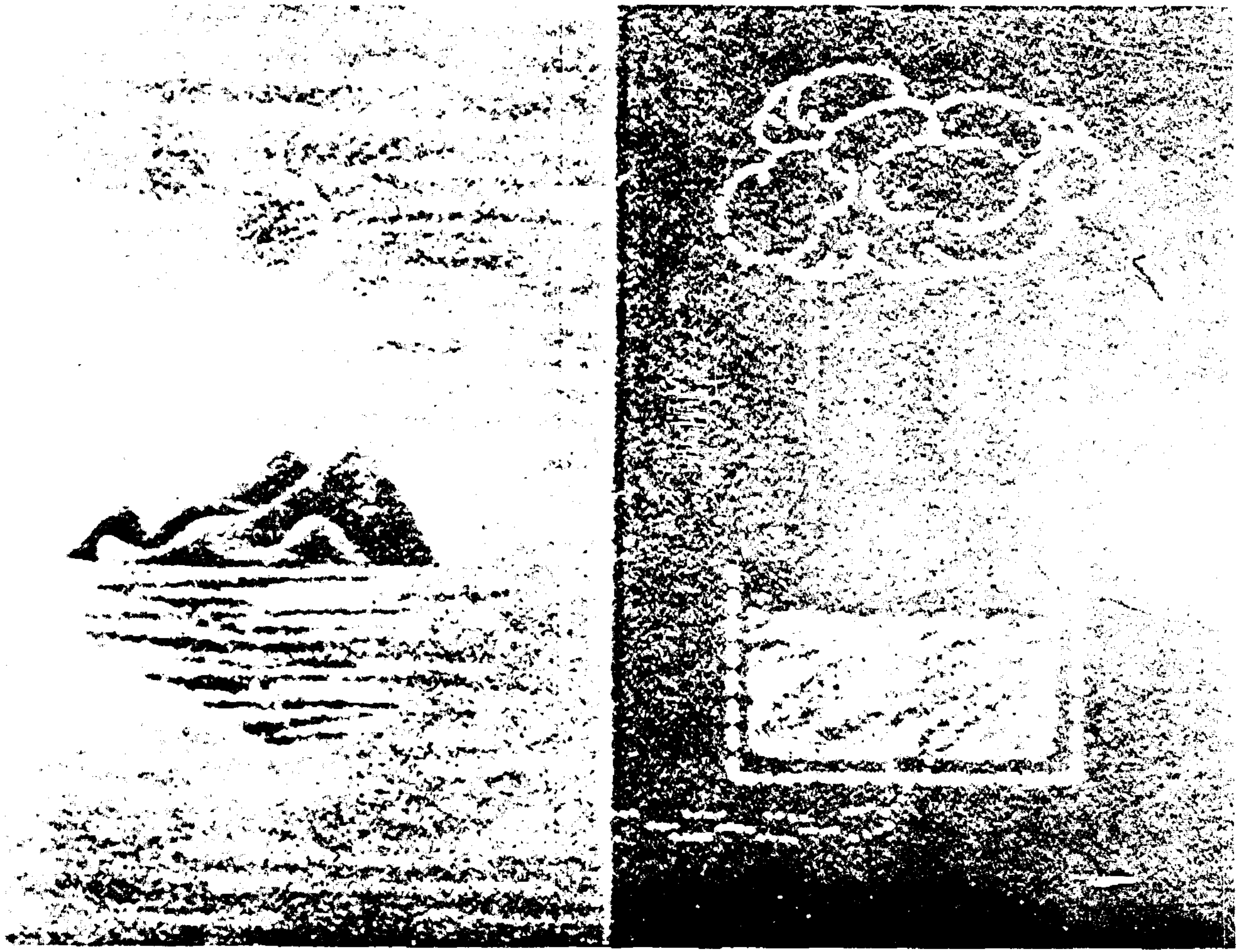


Fig. 19a - Split Screen, Right-Left Filled

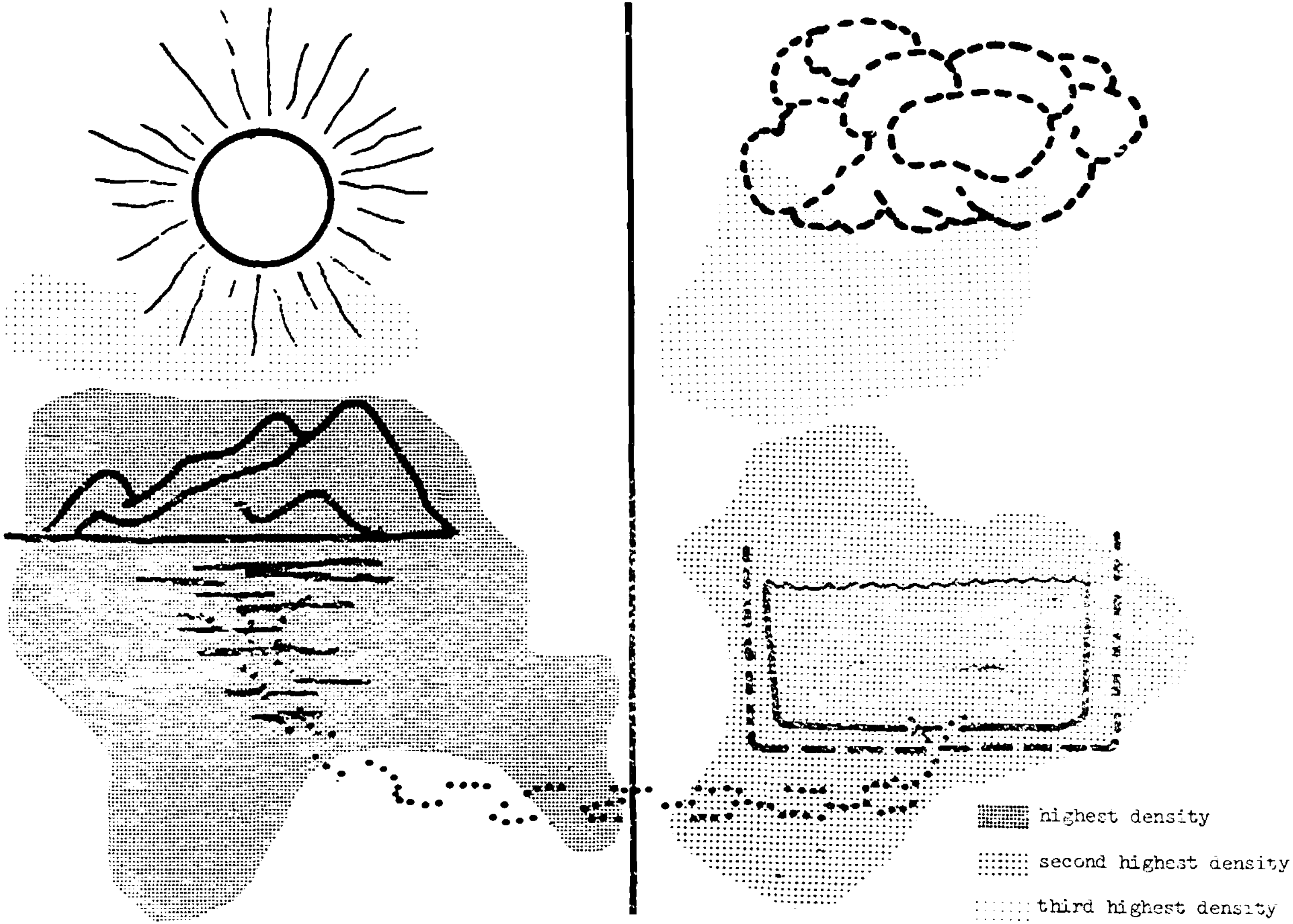


Fig. 19b - Density for High I.Q. Subjects on Scene 2[illegible].20

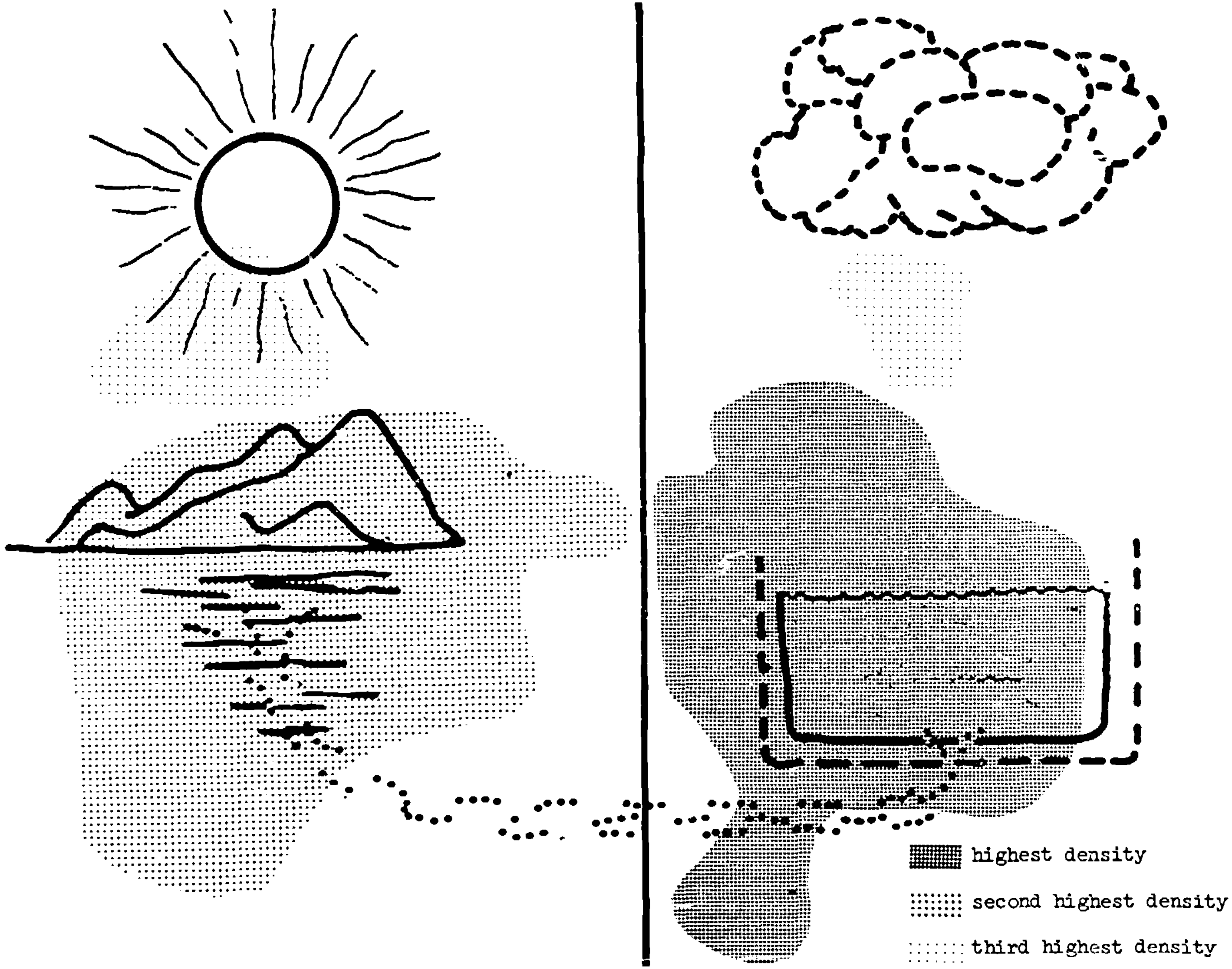


Fig. 19c - Density for Low I.Q. Subjects on Scene 26.20

Table XXVII - Proportions of Eye Markers Falling on Visual Areas of Scenes 26.10 and 26.20

Visual areas within scenes / Groups	Scene 26.10 (Right Side Filled)		Scene 26.20 (Both Sides Filled)	
	Right Side	Left Side	Right Side	Left Side
High IQ	0.797	0.203	0.392	0.608
Low IQ	0.900	0.100	0.559	0.441
High Age	0.900	0.100	0.455	0.546
Middle Age	0.825	0.175	0.539	0.461
Low Age	0.909	0.091	0.520	0.480

Type and Number of Objects. Question 4: When only a single, static object appears on the screen, will subjects' eye markers tend to cluster around this object rather than being scattered throughout the area of the screen?

This question is somewhat similar to the first part of the one preceding in that all of the area surrounding the single, static object is blank. Two scenes in which a simple object--a large drop of water--appears in the center of the screen were used for this analysis. Analysis of the water drop the first time it appears showed that 98% of the eye markers fell on or immediately around it. The situation was quite similar in the second scene with 94% of the subjects' markers located on the water drop.

In this instance, the single object drew the attention of the subjects. This indicates the effectiveness of placing only one object at a time in the scene if focused attention is definitely needed. This scene has the classification of Simple, Static, and Unicenter. When the eye markers of the same group of subjects on another scene which has the classification Simple, Static, and Multicenter were analyzed, a quite different pattern of viewing was evident. In the latter scene, 31.10, the subjects had many density clusters; i.e., they looked at many places on the screen. This indicates that the number of objects on the screen does affect the pattern of viewing.

Movement. Question 5: On a scene in which it appears that a foreground object is slowly moving, will subjects look in the area of movement more than in the seemingly stable regions of the scene?

In the scene used to answer this question, the "slowly-moving object" is a dramatized cold front moving toward a city. In actuality, the cold front only gives the appearance of movement since the background and city are moving instead. The foreground immediately below the front does not move. It was thought that the cold front would induce tracking and thus the subjects' eye markers would appear on the front. Thirty-two percent of the subjects' eye markers are found in the area of the front. However, 34% of the markers are located in the stable foreground region below the moving front and the city. Twenty percent of the eye markers fall on the city and 14% on the moving background. Thus the subjects divide their attention fairly well among the seemingly moving front, the stable foreground region below the front and city, and the background and city which are actually moving. A summary of the proportions of subjects' eye markers which are found in the various object areas is given in Table XXVIII and the density of subjects' eye markers are shown in Fig. 20b.

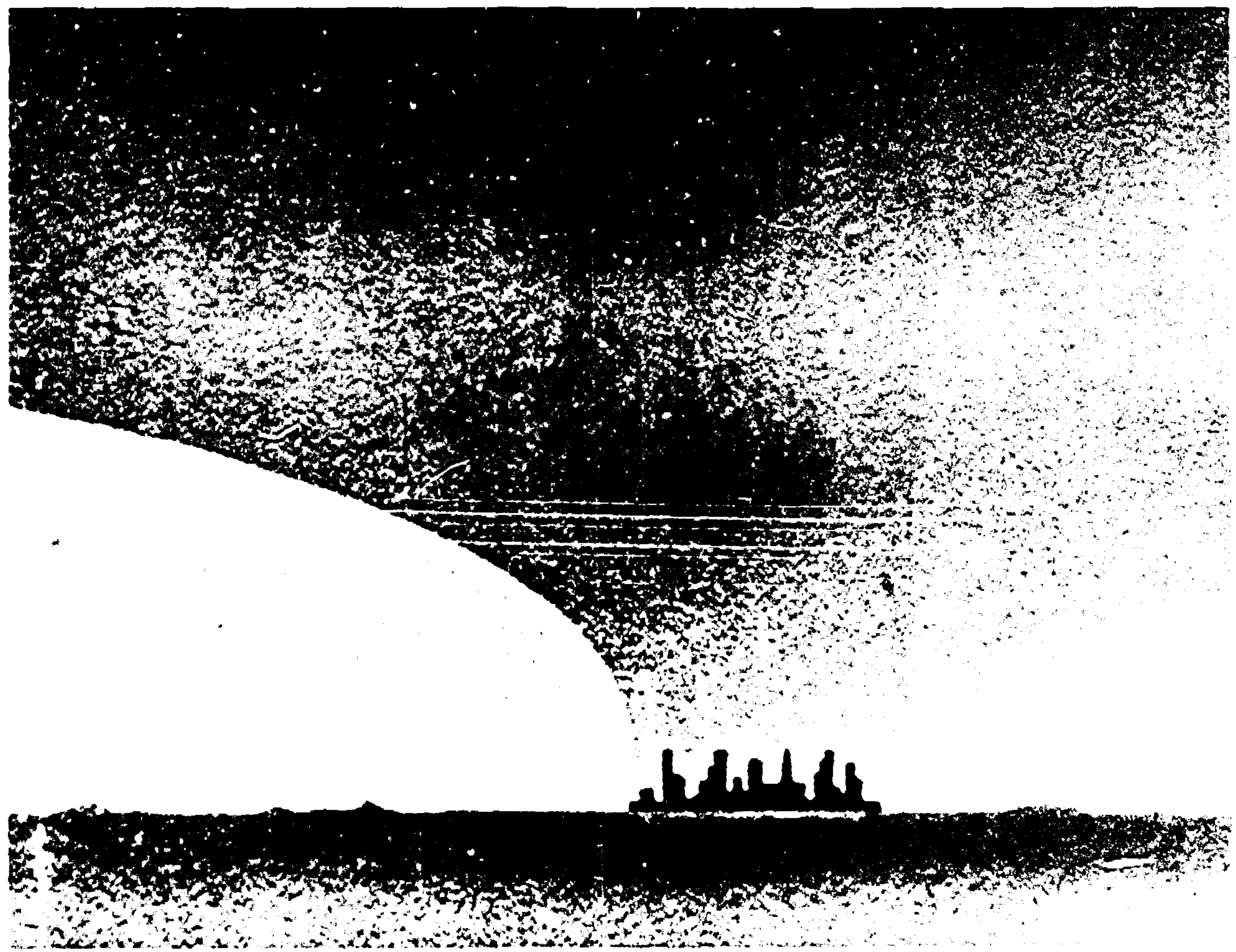


Fig. 20a - Scene 7.10 Cold Front Moving into City

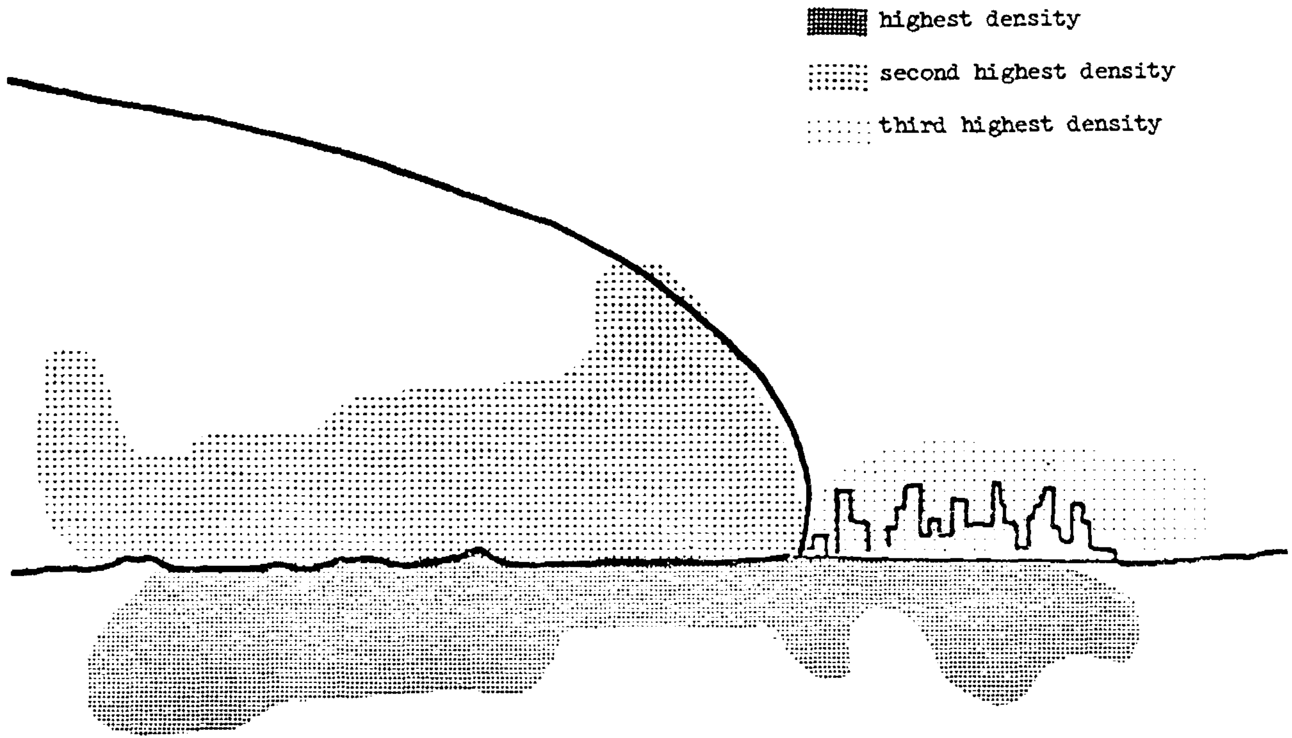


Fig. 20b - Density for Selected Subjects on Scene 7.10

Table XXVIII - Proportions of Eye Markers Falling on Visual Areas of Scene 7.10

Visual Area	Proportions
Foreground	0.340
Cold Front	0.321
City	0.197
Other (Background)	0.140

Movement. Question 6: On a scene in which there are quick transitions from subscene to subscene will the subjects concentrate their attention on the center of the screen rather than attempt to follow the action? That is, does the "Surrender Phenomenon," observed in the pilot study, occur?

In the pilot study when an extremely fast-paced sequence was used as the stimulus, the subjects attempted to follow the moving objects when they first appeared but then this initial tendency was replaced by a concentration only on the center of the screen. Since the subscenes in that sequence were introduced by quick cuts, a sequence from the present stimulus which was introduced in a similar manner was analyzed to determine if the subjects' eye-movement responses are similar. Analysis of eye marker density data for these scenes reveals that subjects do look predominantly in the central area of the screen. Ninety-four percent of the eye markers are found in this region. It should be noted, however, that in several of the subscenes the major object of interest is located approximately in the center of the stimulus field. In the remainder, the stimuli are scattered throughout the screen. The analysis of the pilot data and the data from this study indicate that scenes introduced by quick cuts which are dynamically complex elicit a central fixation tendency. Caution must be used in interpreting these data; however, since a confounding factor is present.

Cues--Auditory. Question 7: On a scene where an auditory cue is given, will the subjects concentrate more heavily in the area referred to by the cue than on other elements of the scene? Are there differences in the eye-movement responses to the auditory cue according to the intelligence level of the subject?

To answer this question an analysis was made of Scene 11.31 from Piloting and Control of an Airplane in which the narrator specifically directs the subjects to a particular stimulus area through the use of an auditory cue. The specific area to which the narrator refers

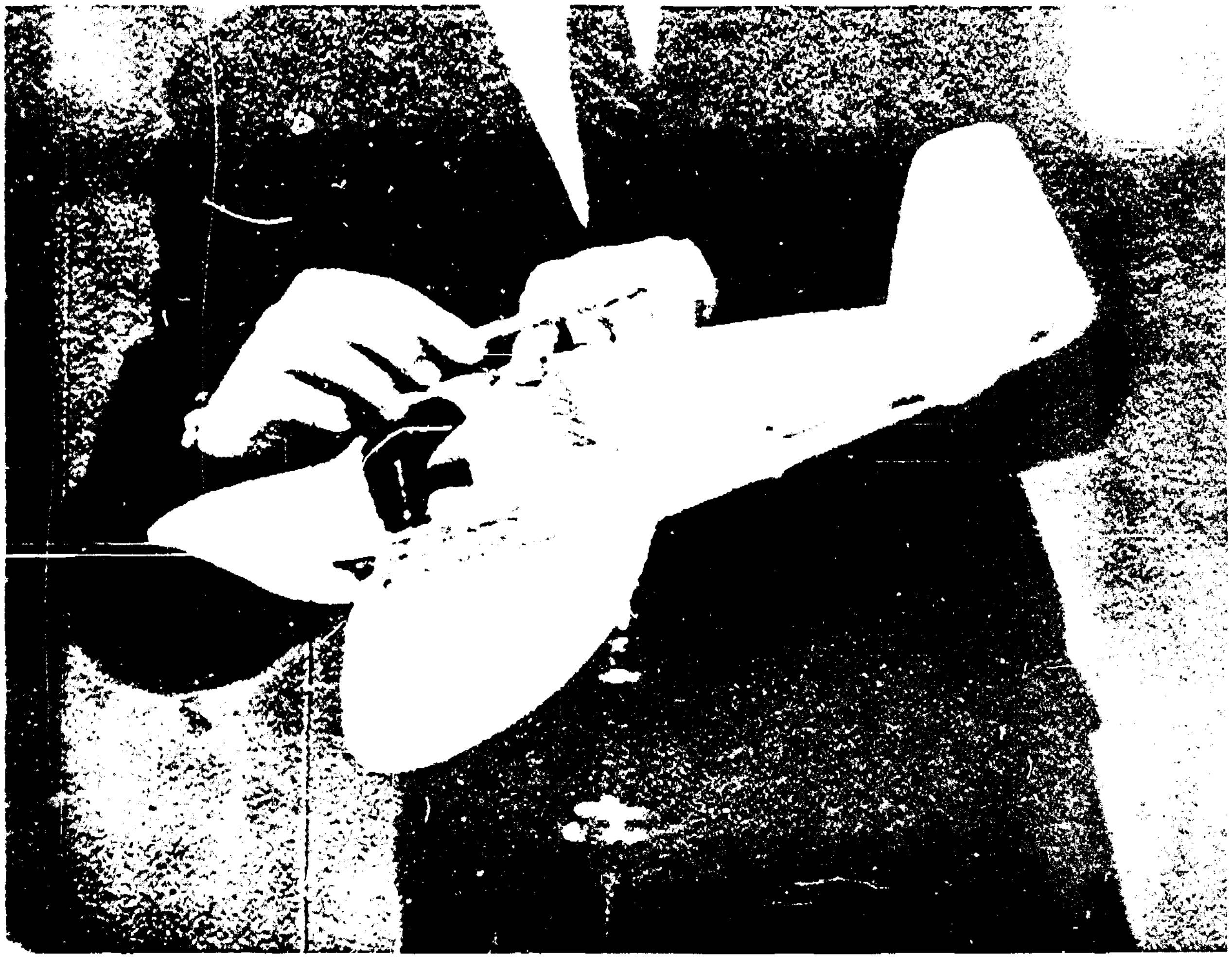


Fig. 21a - Scene 11.31 Auditory Cue

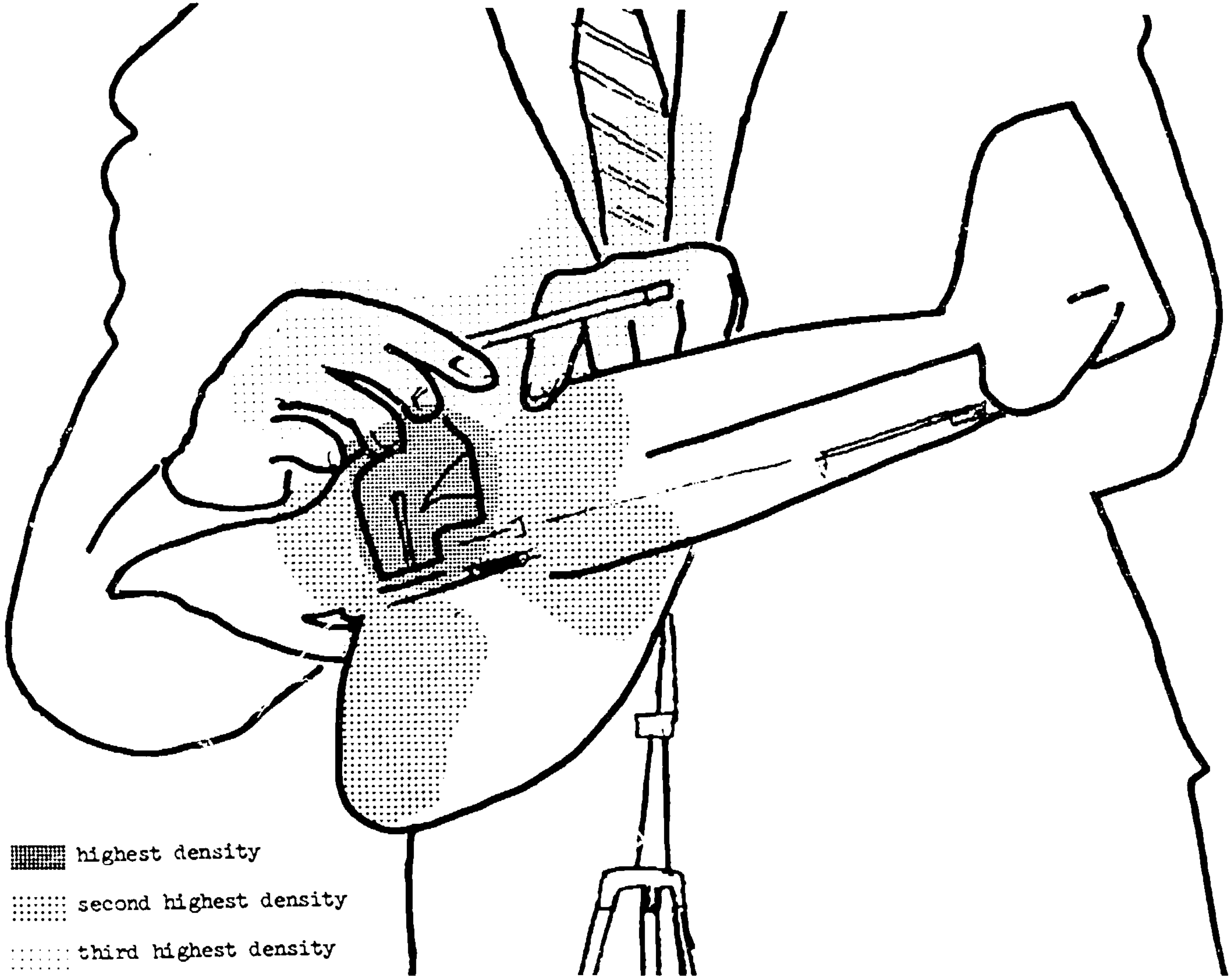


Fig. 21b - Density for Selected Subjects on Scene 11.31

is the crossing of the narrator's finger and a pencil. The subjects for the most part do not focus their attention on that region--it receives only 19% of the subjects' eye markers. The subjects look more at various aspects of the plane that appears in the same scene. Sixty-five percent of the subjects' eye markers fall on the plane, as can be seen in Table XXIX.

Table XXIX - Proportions of Eye Markers Falling on Visual Areas of Scene 11.31

Visual Areas / Groups	Audio Cue Area	Plane and Cockpit	Other
Selected Subjects	0.191	0.653	0.155
High IQ	0.125	0.823	0.051
Low IQ	0.221	0.612	0.167

When the difference between the High and Low Intelligence groups is analyzed, it is found that there is no appreciable difference in their viewing patterns. Relatively speaking, the Low IQ group does look more at the particular area to which the auditory cue is directed than does the High IQ group. The proportions of eye markers falling in this area are 22% and 13%, respectively, for the two groups. There does seem to be a rather appreciable difference between the two groups with regard to where the remainder of their eye markers fall. Eighty-two percent of the High IQ subjects' markers are located in the region of the plane, whereas 61% of the Low IQ subjects' markers are focused there with 17% of the latter group's eye markers on other areas of the screen.

Generally speaking, a possible explanation of these results could be that even though the narrator does direct the viewer to a specific area, the subject matter to which he is referring concerns elements of the plane. This explanation might be an alternative to a simpler interpretation--that aspects of the plane were more interesting to the subjects.

Cues--Visual. Question 8: On a scene where a visual cue in the form of a superimposed word appears on the screen, will the subjects concentrate their attention more on the cue than on other elements of the scene? Will there be differences in the viewing pattern of intelligence groups on this scene?

This question is somewhat similar to the one immediately preceding except that this stimulus area is defined by a visual cue. In a scene from Piloting and Control of an Airplane, the narrator is demonstrating the "Pitch" of an airplane with the word "Pitch" superimposed on the screen. As with the auditory cue scene, the majority (41%) of eye markers fall within the area of the plane. This is true for both the High IQ and the Low IQ subjects (55% and 51%, respectively). Of the major stimulus areas of this scene, "Pitch" receives the least density of eye markers. It is possible that the subjects did read the word since it has only five letters and 14% of the markers do fall in that area (see Table XXX). That many of the subjects did read the superimposed word is somewhat substantiated by comparing Scene 14.2 with Scene 14.3. These two scenes are the same visually except in the latter, the word "Pitch" appears. Combining the stand area with the "Pitch" area, since the stand area in 14.2 includes the area where the superimposed word appears in 14.3, it may be noticed that there is a shift in emphasis between these two scenes. As shown in Table XXXI, more eye markers are centered in the stand and pitch area on Scene 14.3 than on 14.2 particularly for the High IQ group. This shows that the superimposed word does attract the attention of at least a few subjects.

Table XXX - Proportions of Eye Markers Falling on Visual Areas of Scene 14.30

Visual Areas / Groups	Plane	Stand	"Pitch"	Other
Selected Subjects	0.412	0.395	0.136	0.056
High IQ	0.550	0.239	0.150	0.058
Low IQ	0.514	0.251	0.083	0.149

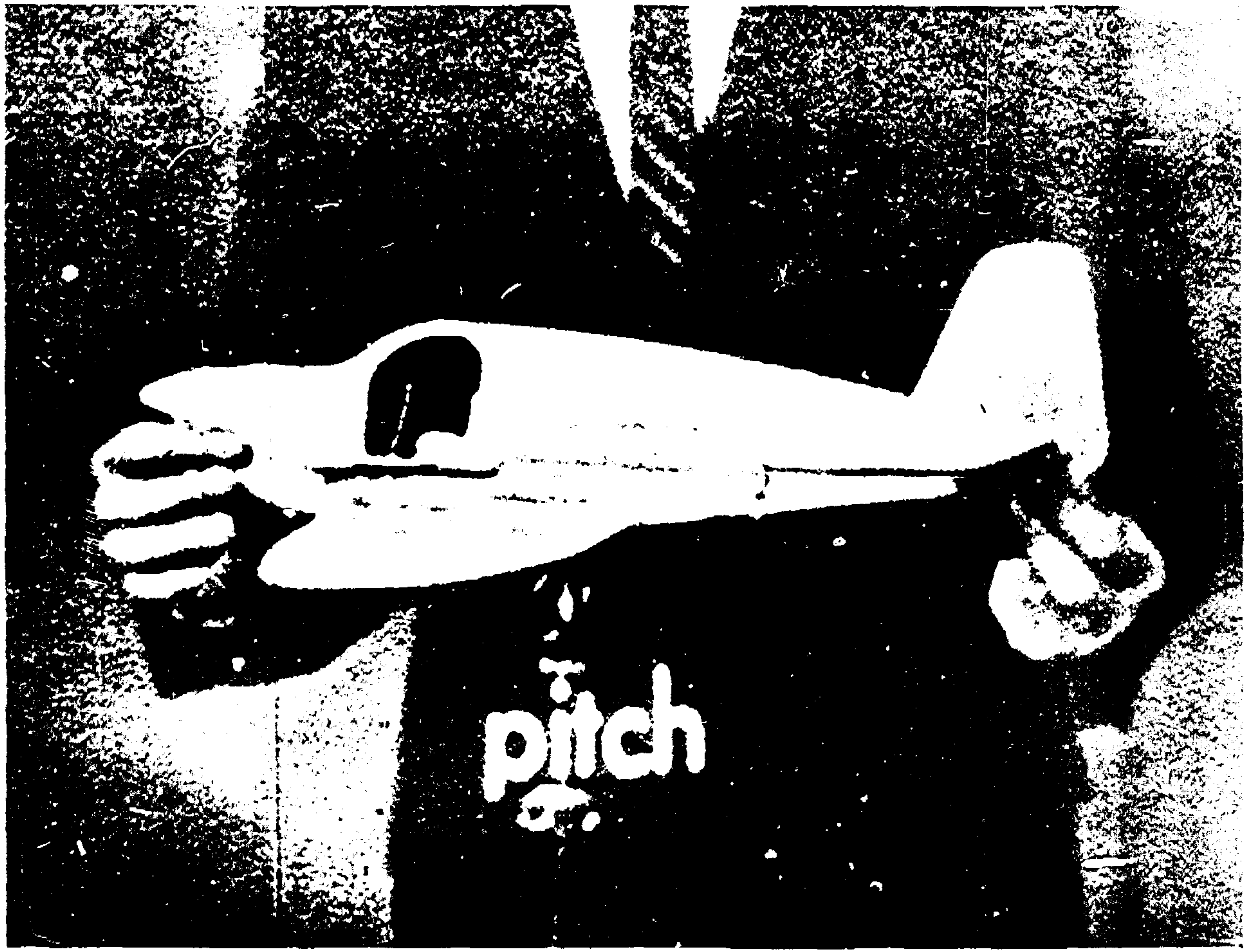
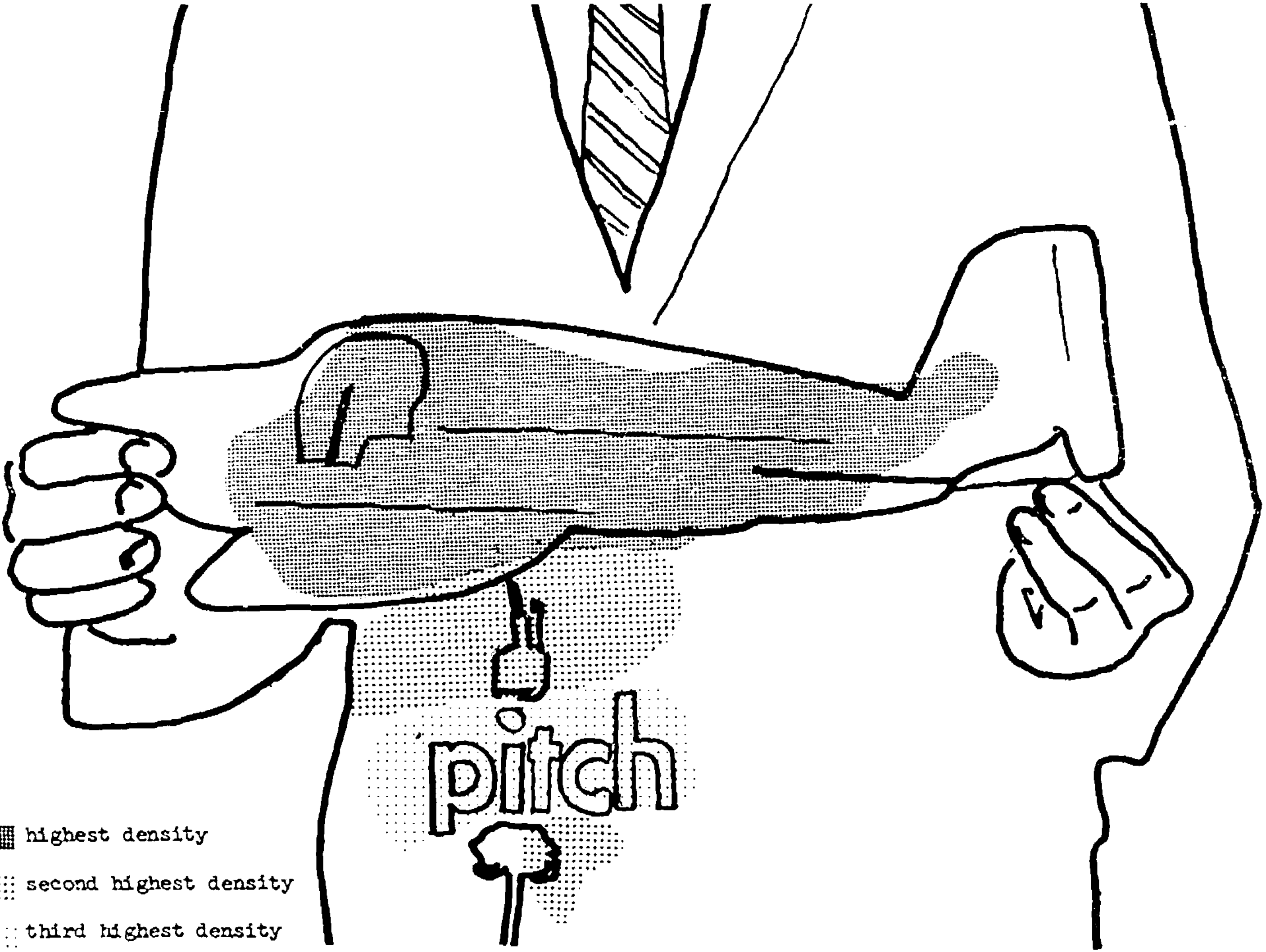


Fig. 22a - Scene 14.3 Visual Cue "Pitch"



highest density

second highest density

third highest density

Fig. 22b - Density for High I.Q. Subjects on Scene 14.3

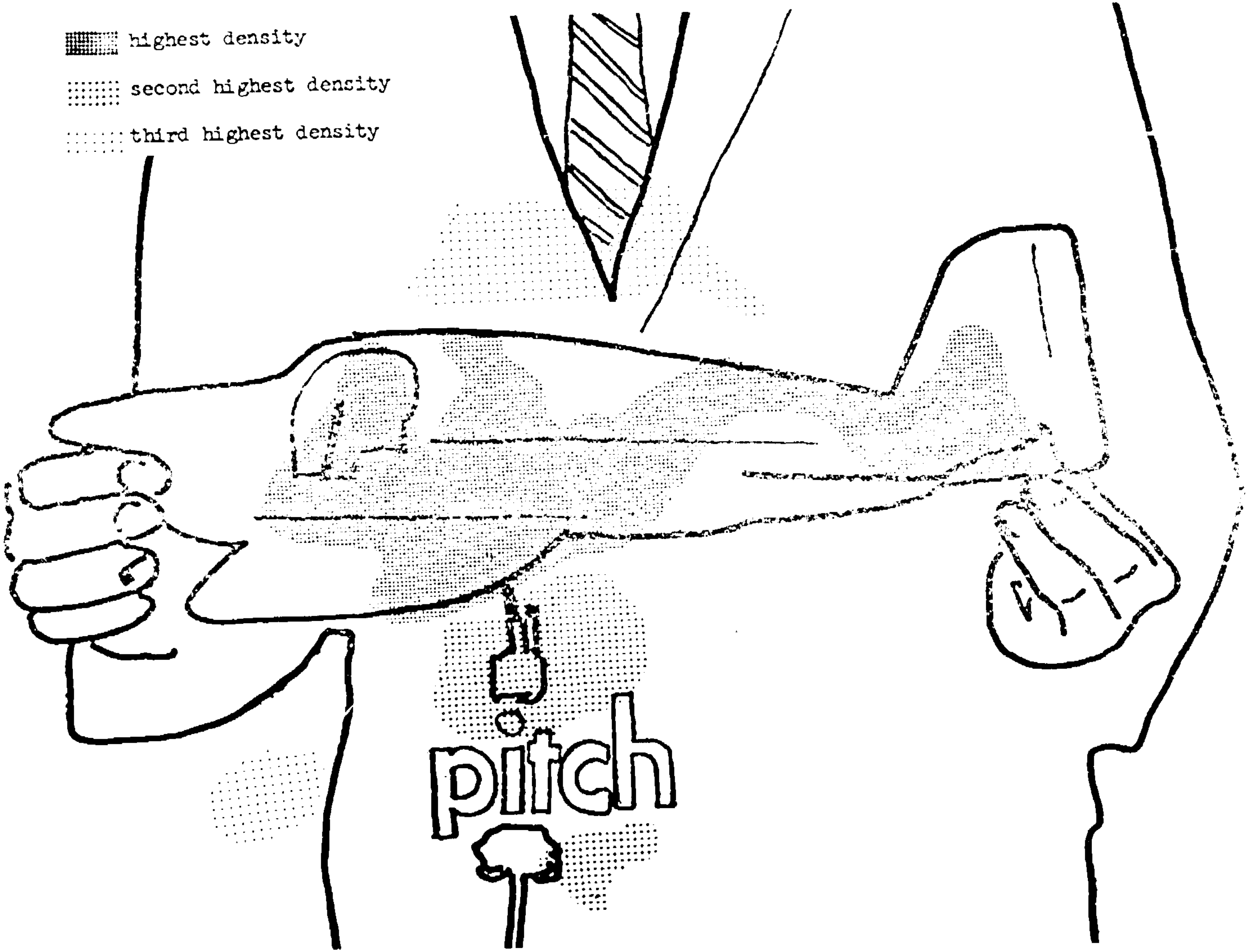


Fig. 22c - Density for Low I.Q. Subjects on Scene 14.3

Table XXXI - Proportions of Eye Markers Falling on Visual Areas of Scenes 14.2 and 14.3 for High and Low IQ Groups

Scene	High IQ		Low IQ	
	14.2	14.3	14.2	14.3
Plane	0.599	0.550	0.536	0.514
Stand and "Pitch" Areas	0.247	0.389	0.273	0.334
Other	0.153	0.058	0.190	0.149

Repeated Presentation of a Scene. Question 9: On two scenes which are the same in visual content but which are introduced at different points in the stimulus film will the subjects display similar viewing patterns on the two scenes? Will there be different viewing patterns exhibited by different IQ and different age groups?

Comparisons were made on scenes with identical visual content which were introduced at different points in the stimulus film. This was done to determine the constancy of the eye markers for identical stimulus areas for (1) the total group of subjects, (2) High IQ vs Low IQ groups, and (3) High Age vs Middle Age vs Low Age groups. The scene used to answer these questions is from an Ajax commercial which has three identifiable areas: (1) words on the right, (2) box with words on the left, and (3) other (i.e., areas into which eye markers fall but which are not definable by the two major areas).

In the initial scene, all subjects seem to concentrate their attention for a majority of the time on the words on the right side, with 52% of their eye markers located in that area. Twenty-three percent of the eye markers fall on the box area with the remainder falling on "other." On the second identical scene, the words still draw slightly more attention than the box area, receiving 40% of the eye markers; however, the box area now seems to elicit greater interest than before with 36% of the markers focused there.

The analysis of the viewing patterns of the IQ groups on the first commercial scene shows the High IQ group to concentrate a great portion of the time on the words (60%) and relatively little on the box (19%). On the second scene, the area receiving the most attention is reversed for this group with 36% of their eye markers falling on the words and 56% on the box. On the other hand, the Low IQ group's visual pattern is fairly constant with regard to the two scenes. Forty-two percent of their eye markers fall on the words in the first scene with 45% of them falling in this same area on the second. The Low IQ group's response is similar with respect to the box area since the density of their eye markers is 28% on this area in the initial scene and 31% on the second. The differences between the IQ groups is shown in Figs. 23b-23c.

Analysis of eye marker concentration for varying age groups on these two scenes reveals results similar to those of the intelligence groups. The High Age group's eye markers fall on the words a great deal of the time on the first scene (63%) with relatively little attention given to the box (19%). On the second scene, the eye marker concentration on the words drops to 35% while the concentration on the box is raised to 46% for this group. In comparison, on the first scene the Low Age subjects attend primarily to the words (44%) with the box also attracting their interest (34%). On the second scene, their responses remain fairly stable in that 43% of the markers are located on the words and 35% of the markers are located on the box. The Middle Age group manifests the same general pattern as does the Low Age group on the two scenes, but to a much lesser extent. Their eye marker concentration goes from a 46% density to a 42% density on the words and from 17% to 28% on the box.

If one were to exclude the Middle Age group, the viewing patterns of the High vs Low groups on both age and IQ are almost identical. Considering only the data on the age groupings, there seems to be a general tendency of a mobility of viewing to a stability of viewing on a repeated scene as one proceeds from older subjects to younger ones. A similar tendency, although to a lesser degree, is noticed with regard to High IQ vs Low IQ subjects.

A possible explanation for such results may be that a time factor is involved. Perhaps it took the Lower IQ or Age groups longer to read the words on the right, and thus they still focused in this area on the second scene. The High IQ and/or Age groups may have finished reading the words on the first scene and the reappearing scene gave them an opportunity to explore stimuli in the scene which they had not viewed in the initial presentation. The results of this analysis for the

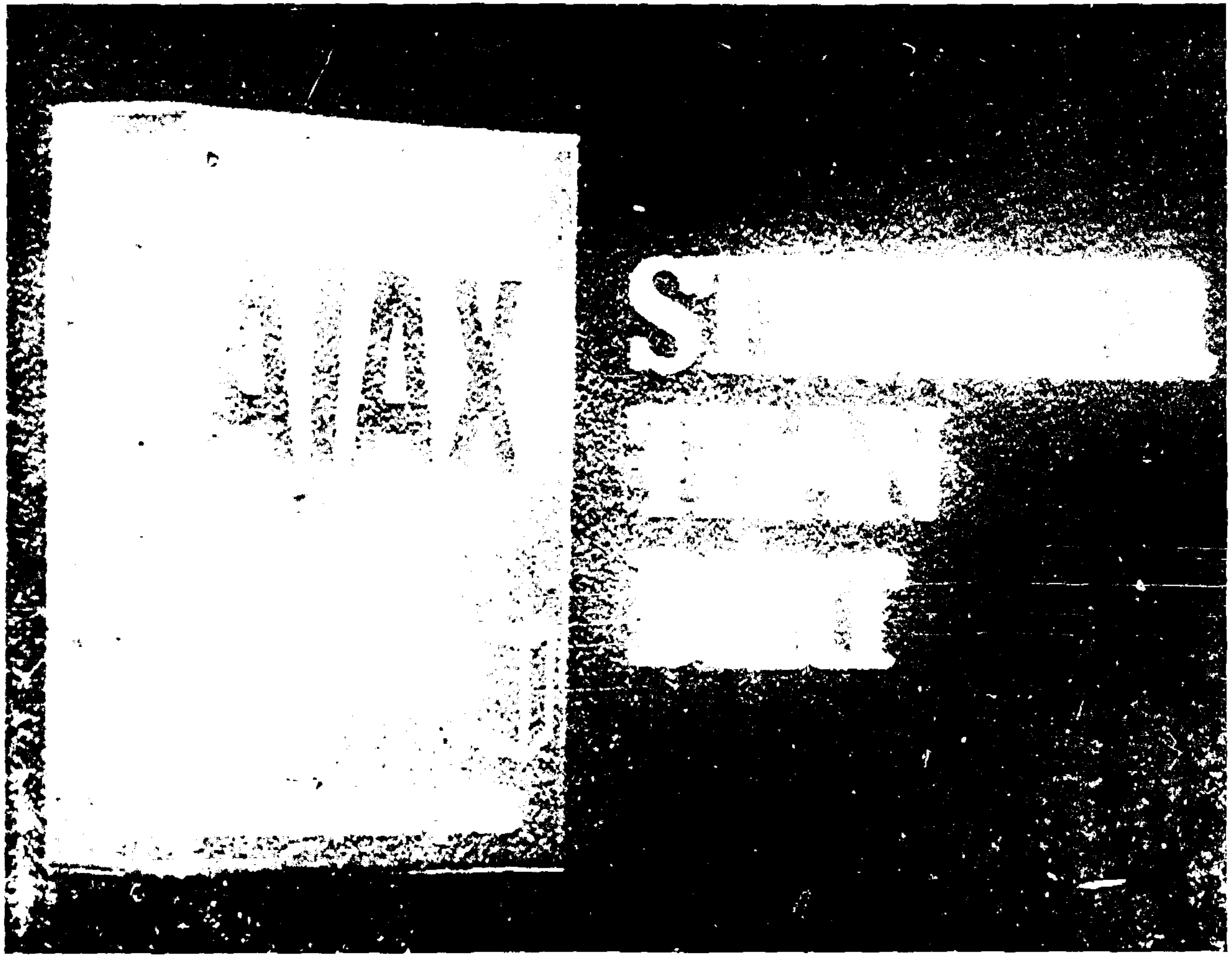


Fig. 23a - Scenes 17.30 and 17.60 Ajax Commercial

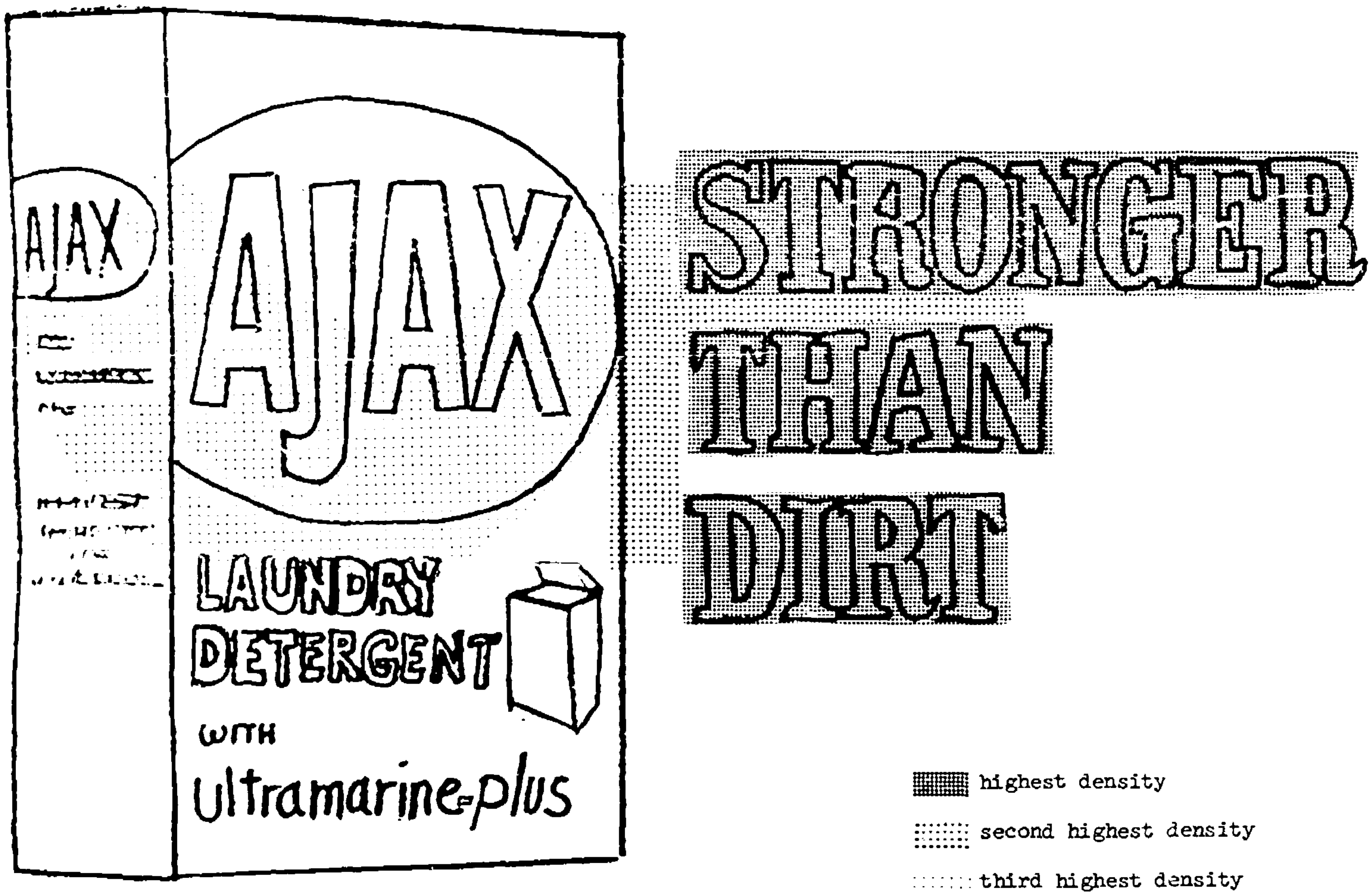


Fig. 23b - Density for High I.Q. Subjects on Scene 17.30

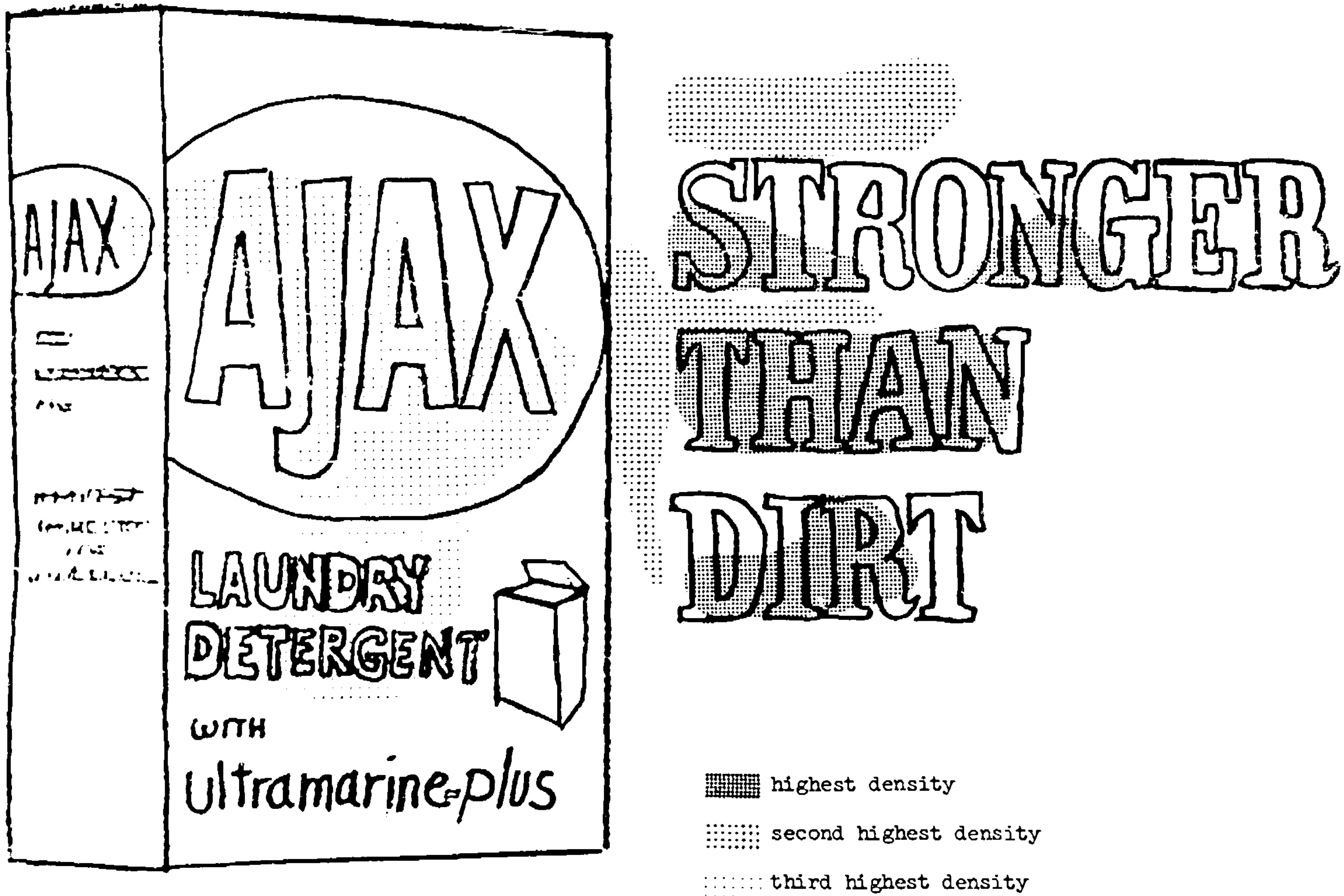


Fig. 23c - Density for Low I.Q. Subjects on Scene 17.30

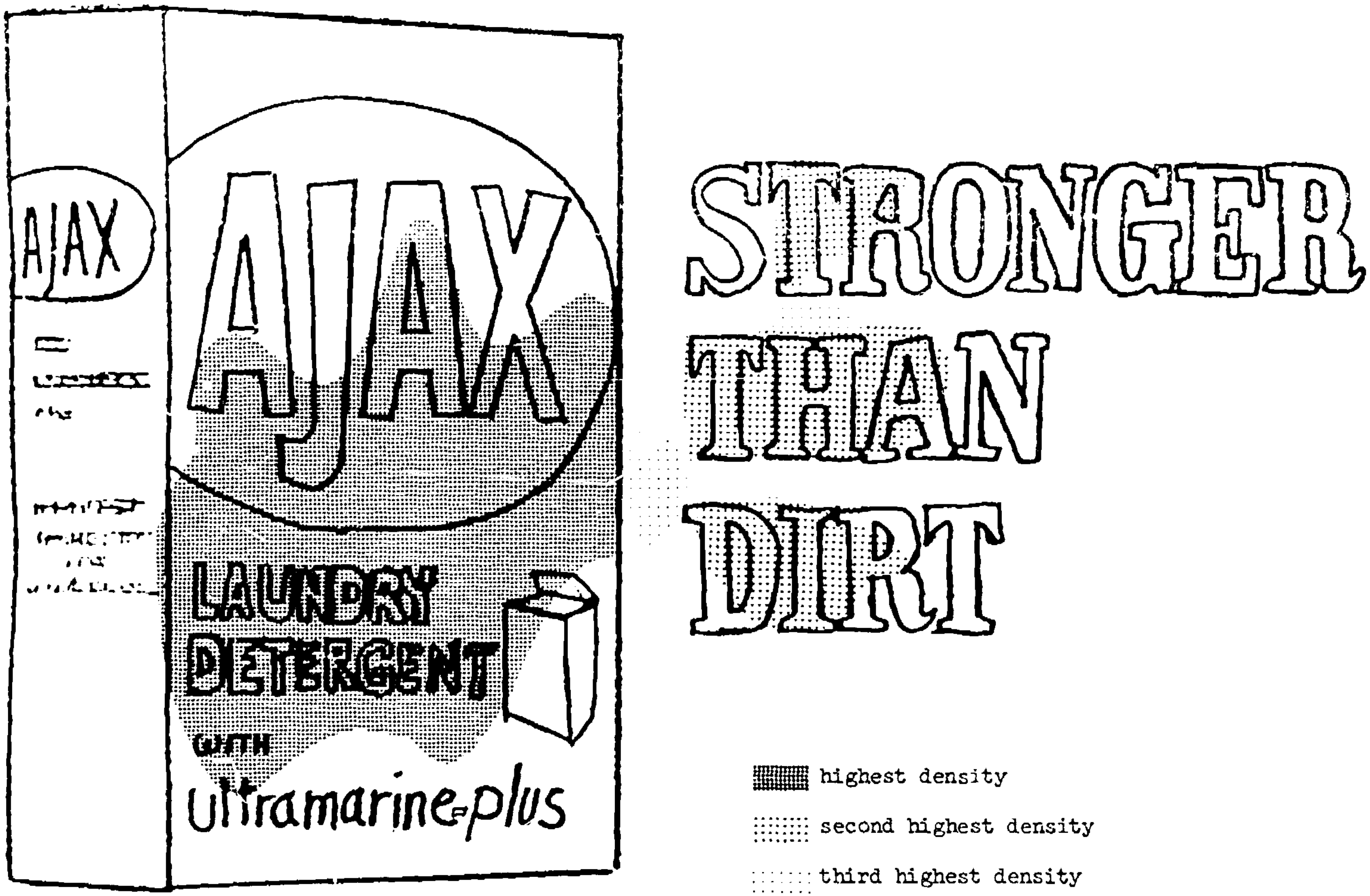


Fig. 23d - Density for High I.Q. Subjects on Scene 17.:0

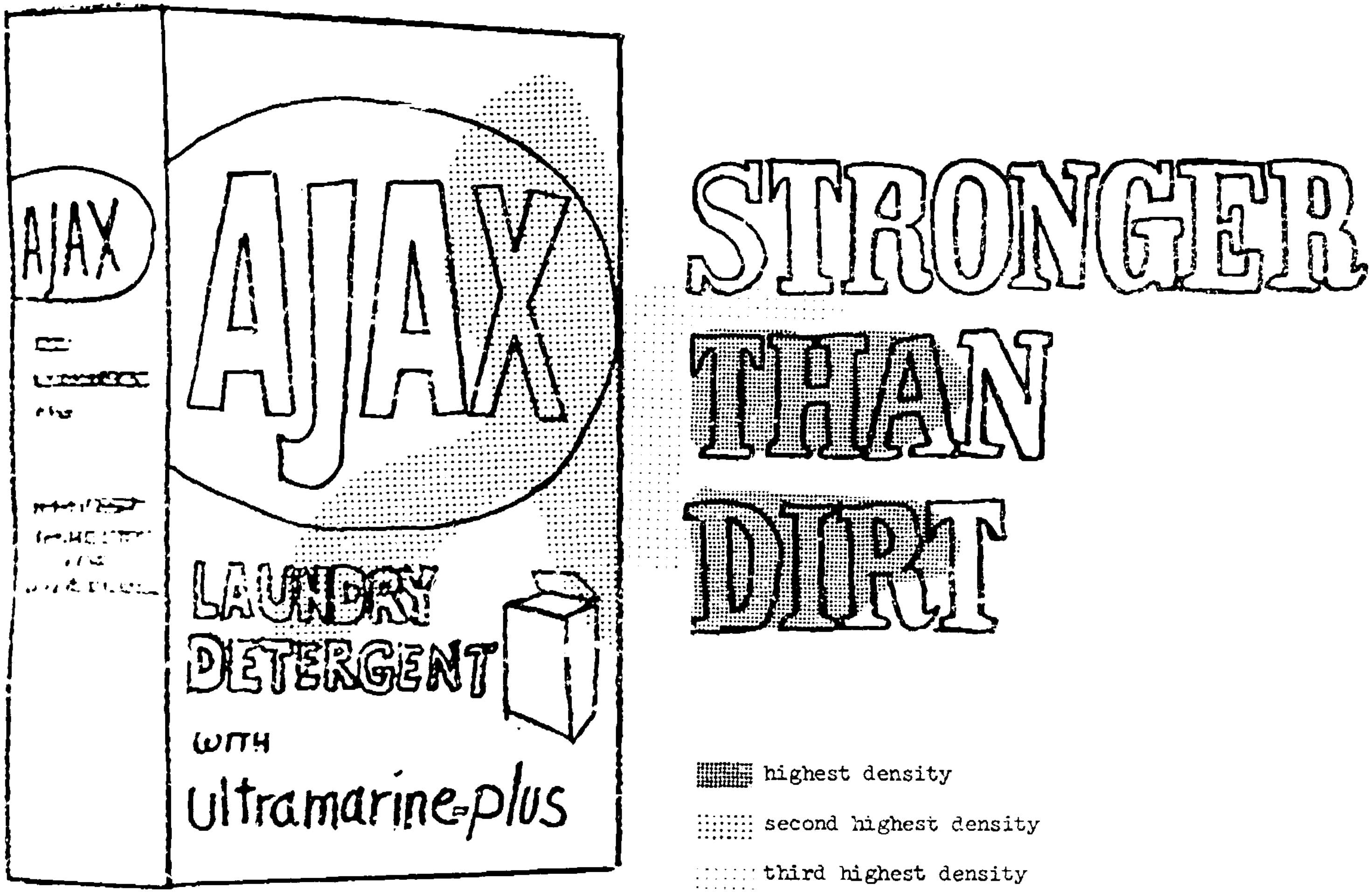


Fig. 23e - Density for Low I.Q. Subjects on Scene 17.0

respective groups is given in Table XXXII.

Table XXXII - Proportions of Eye Markers Falling on Visual Areas of Scenes 17.30 and 17.60

Groups \ Visual Areas within Scenes	Scene 17.30			Scene 17.60		
	Words	Box	Other	Words	Box	Other
All Subjects	0.515	0.230	0.255	0.397	0.362	0.239
High IQ	0.601	0.194	0.205	0.355	0.557	0.088
Low IQ	0.420	0.278	0.302	0.451	0.313	0.236
High Age	0.627	0.193	0.180	0.348	0.455	0.197
Middle Age	0.454	0.178	0.368	0.416	0.282	0.302
Low Age	0.441	0.344	0.215	0.431	0.347	0.222

Summary and Discussion of Results of the Density Analysis. The density analysis was conducted to determine where the subjects look on the visual stimulus. As in the pilot study, the subjects concentrate their attention in a few well-defined areas in most scenes. Questions were asked in the present study concerning what elements of the scene affect this pattern of looking. The effect of the following elements was considered: Novelty of the Objects, Type and Number of Objects, Motion, Auditory and Visual Cues and Repetition of a Scene.

Studies by Berlyne[2] and others have shown that Novel objects attract the subjects' attention. Novelty is also found in this study to have a decided influence on the pattern of viewing. A series of scenes (2.3-2.8) were analyzed to answer the question on novelty. In scenes 2.4-2.8 only one new element is added to each otherwise unchanged scene. Subjects look in the area of the new element more on Scenes 2.4-2.7 than at any other area of the screen. However, when the last scene in the sequence--Scene 2.8--appears, the subjects' eye markers scatter. This may result from the fact that the scene has a number of elements and may be too "busy" visually thus distracting the subjects from the new object. In each scene, the new element is also slowly moving. Further research to determine if all novel objects, or only certain types, attract the attention of subjects might prove useful.

The response of the subjects to the last scene in the sequence suggests that the number of objects influences the viewing pattern. This is verified by the analysis of scenes with a varying number of objects. In one scene with only one central object--classified as Simple. Static, and Unicenter--subjects look at that object approximately 90% of the time. When a scene with many objects was analyzed--classified as Simple, Static and Multicenter--the subjects' eye-movement responses separated into a number of clusters. When producers wish to draw definite attention to specific objects in a scene, reducing the number of objects appears to be an effective technique. Surrounding the object by blank space also appears to be effective as was observed in the scene with the one object, as well as the scene with the Split Screen which has the blank space on one side.

In considering the type of object as it affects the eye movements, one question was concerned with a visible narrator. The question asked was whether the subjects would look at the narrator's face more than at any other area of the screen. This question is related to a finding in the pilot study where subjects often stared at the narrator's face to the exclusion of demonstration items. Since many films and telelessons present concepts by means of a visible narrator, it was considered important to check this finding with another sample of subjects and a different stimulus film. Several scenes with a visible narrator were analyzed. It was found that the subjects look more often at areas in the scene other than the narrator's face including the narrator's tie and torso, the plane which is the object of demonstration, and the narrator's hand and pencil when he is using them to demonstrate. This finding shows that a narrator's face is not inherently appealing, but that the areas of attention depend upon the other objects in the scene. It should be noted, however, that on Scenes 10.10 where the narrator has not started to manipulate the plane and 15.30, which is the last scene in the sequence, a fairly large proportion of the time (ranging from 73% to 44%) is spent on the areas of the face combined with the tie and torso. Thus a great portion of time is spent on the narrator. Producers should take this into consideration and possibly eliminate the visible narrator if the object being demonstrated is of more importance.

One type of motion used by producers is that in which the background moves instead of the foreground. In such scenes, objects often appear to move when they are actually static. Scene 7.10 was analyzed in this study to determine if the reverse motion draws the attention of the subjects to the seemingly moving object--a cold front "moving" into a city. Subjects are not attracted to the area of apparent motion any more than to other areas of the screen. The cold front receives 32% of the eye markers while the stable foreground area immediately below the front receives 34%. Other areas, including the city and the background, also receive 34% of the eye markers. This technique, therefore, results in drawing the subjects' attention equally to different areas of the screen. Thus this type of motion does not appear too effective if the producers wish to draw the attention of the subjects to the "moving" object. The analysis of eye-movement indices shows that motion significantly affects how the subjects view a scene. Future studies to consider the influence of different types of motion on both how and where the subjects look would appear to be quite fruitful.

An observation in the pilot study was that subjects tended to look at the center of the screen when a fast-paced sequence introduced by quick cuts appeared. When a scene with quick cuts was analyzed in this study, the same phenomenon occurred. Subjects looked in the center of the screen almost exclusively. This may have been caused by the central placement of objects in many of the scenes; however, several scenes contained objects widely spread throughout the screen. Studies which control for object placement and the quick cuts production technique are needed. Future research should also consider whether the subjects' tendency toward the center of the screen when such a sequence occurs is a coping phenomenon or a withdrawal from a difficult task. The subjects could be asked specific questions on their perceptions to ascertain the effectiveness of the central pattern of viewing.

When the effects of a direct auditory cue and a visual cue in the form of a superimposed word were analyzed, it was found that these cues only draw the subjects' attention to the specific areas to a small extent. Other types of visuals appear more effective than the superimposed word. Research on the most effective type of auditory cue is needed.

One aspect of the density analysis was a comparison between High and Low IQ groups on many of the scenes. The most pronounced difference between these two groups occurs on two of the scene sequences which have recurring elements: (1) the scene from the Ajax commercial which has words on the right and a box with words on the left and which appears twice in the commercial, and (2) the Split Screen sequence which has one blank side and one side filled with objects in 26.10 and both sides filled with objects in 26.20. On both of these sequences, the High IQ subjects show a mobility of viewing in that they shift their center of attention from the objects they viewed in the first scene to other objects when the second scene in each sequence appears. In contrast, the Low IQ subjects show a stability in viewing in that they still look mainly at the objects viewed in the first scene when the second scene of each sequence appears. The viewing pattern for both groups is fairly consistent for these two sequences. The difference between IQ groups may be related to speed in responding to the stimulus. On the scene from the Ajax commercial, the High IQ subjects may be faster readers and thus they were ready to move to other stimuli the second time the scene appeared. Similarly, on the Split Screen sequence, they may have taken a shorter time to respond to the objects on the filled side of the screen and thus were ready to move to the new objects which were presented in 26.20. For the Low IQ subjects, the opposite may have been true. This explanation appears to be the most plausible although another possibility is that the Low IQ subjects found certain objects more interesting than others and thus those objects retained their attention longer.

Comparisons were also made on a few scenes between High Age, Middle Age, and Low Age groups. The only striking difference occurs between the High Age and Low Age groups on the repeated presentation of the scene from the Ajax commercial. On that sequence, the High Age group responds with a mobility of viewing almost identical to the High IQ group discussed above and the Low Age group responds with a stability of viewing almost identical to the Low IQ group. This response was also evident in the Split Screen sequence although not to as great a degree. The same explanation of speed of reaction as well as interest could be advanced for the difference in the age groups.

CHAPTER IV

CONCLUSIONS

Since this research was exploratory, any conclusions must be considered tentative. With this reservation, the following conclusions may be drawn from the results:

1. Data of children's eye movements gathered while they viewed motion picture films and telelessons fall along a continuum rather than into the dichotomy of fixations and saccades reported by eye-movement researcher in the field of reading.

Four fairly distinct intervals were observed in this continuum and data were classified accordingly. Eye movements falling into these intervals were defined as follows:

No Observable Movements (NOMS)	0-4.2 degrees/second
Minimovements (MINS)	4.2-11.4 degrees/second
Small Saccades	11.4-47.4 degrees/second
Large Saccades	Above 47.4 degrees/second.

That these intervals are distinct is partially supported by some of the correlational analyses. For example, with intelligence as the independent variable, NOMS show a negative correlation, MINS a positive correlation, Small Saccades a negative correlation and Large Saccades a positive correlation.

The eye-movement indices identified parallel, in large part, the types of eye movements observed in the pilot study.

2. Age does not appear to be related to any great extent to the subjects' eye movements.

No significant relationships were found between the ages of subjects and the types of eye movements they display. In addition, the age of the subject influences where he looks only on a few scenes. On one sequence of scenes (Ajax commercial) there is a marked difference between the High Age and Low Age subjects, and on another scene sequence (Split Screen) slight differences occur. Comparisons on these scenes show a mobility of viewing for the High Age subjects and a stability of viewing for the Low Age subjects. In other words, High Age subjects shift their viewing to different objects on the second scene in each sequence while Low Age subjects view the same objects from scene to scene.

3. Intelligence is related to certain eye movements of subjects.

The one predictor variable in the multiple regression equations is intelligence with No Observable Movements and Minimovements. For NOMS, the relationship is negative and for MINS, the relationship is positive. This finding verifies a similar one in the pilot study that a relationship does exist between these eye-movement indices and intelligence. The direction of the relationships in the two studies is opposite, however, since NOMS correlated positively and MINS negatively with intelligence in the pilot study. The indication is that the variable of motion, i.e., whether the scene is Static or Dynamic, may have affected the difference in direction of the relationship in the two studies.

On the density analysis, High and Low IQ subjects display different patterns of viewing on the Ajax commercial sequence and the Split Screen sequence. There is a mobility of viewing from scene to scene in each sequence for the High IQ subjects and a stability of viewing from scene to scene for the Low IQ subjects.

4. Eye-movement indices are not related to the subjects' learning on the stimulus films.

Learning scores were obtained using two instruments, one which tested the subjects' visual recognition of portions of various scenes and the other which tested the subjects' recall and understanding based upon the visual and auditory recall combined. Separate regression analyses were run on each of the four eye-movement indices for both of the learning measures. In no instance did the learning scores add substantially to the prediction of the criteria. This finding adds support to a similar finding in the pilot study where test scores on recall were not found to be related to the eye-movement indices.

5. Various stimulus variables have an effect on the type of eye movements displayed as well as the objects subjects view.

The scene variable which has the most effect on the type of eye-movement indices displayed is motion. Dynamic scenes, when compared to Static scenes, have fewer No Observable Movements, more Minimovements, more Small Saccades and more Large Saccades. Thus scenes with moving objects induce more eye movements than Static scenes. Reversal scenes, when compared with No-Reversal scenes, also induce fewer NOMS, more MINS, more Small Saccades and more Large Saccades. Therefore, they have the same effect on eye movements as do Dynamic scenes.

Novelty and Complexity do not have an influence on the types of eye movements subjects display, but they do influence where the subjects look. Subjects look more at the novel object than at familiar objects in the scene. However, when the scene becomes extremely complex, the subjects no longer look more at the new element. Rather, they divide their eye-movement responses fairly equally among all the objects in the scene.

That Complexity or the number of elements in the field has an effect on where the subjects look was evident when a scene with one object, a simple field, was compared to a scene with several objects, a complex field. On the scene with one object which was surrounded by blank space, 98% of the eye markers were located on that object. When a more complex field was analyzed, the eye markers were scattered among the several objects.

Different types of scene classifications elicit different types of eye movements. Scenes which were classified as Unclear, Multicenter (with widely-spread objects), Unambiguous and having Indirect Auditory Cues elicit more Large Saccades than scenes with classifications of Clear, Unicenter, Ambiguous and having Direct Auditory Cues. Scenes which are classified as Clear and having Arousal characteristics elicit more Small Saccades than classifications of Unclear and Tranquil. Integrative scenes have more NOMS and fewer MINS than Distractive scenes. Other comparisons showed that Unicenter scenes have more MINS than Multicenter scenes, and Ambiguous scenes have more NOMS than Unambiguous scenes. Thus, various scene variables influence eye movements. The most influential are the classifications of Dynamic-Static and Reversal-No-Reversal. The eye-movement index influenced the most by scene variables is the Large Saccades. It appears from the data analysis that scene variables are more influential than the type of film on eye-movement indices.

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APPENDICES

APPENDIX A

LETTERS TO PARENTS

Below is a copy of the letters sent to the parents of one group of subjects, the high school students, requesting permission for their child to participate in the experiment.

Dear Parents:

Some eleventh graders at _____ High School are being considered for participation in a current research project sponsored by the United States Office of Education and carried out at The Ohio State University by the Bureau of Educational Research and Service. The title of the project is "Educational Television and Perception."

With your permission, one day in the near future your child will be one of a group brought from school to the University in a car driven by one of the research staff for a complete eye examination at the University's Optometric Clinic. You will be informed should the examination reveal that your child needs corrective lenses.

Later in the spring a few youngsters will be returned to the University singly for a two-hour period during which they will watch an educational television program under controlled experimental conditions. During the viewing the child will be wearing on his head an experimental apparatus which will be fitted to him to assure maximum comfort. This apparatus has been used previously with pupils in a similar study. If you have any question regarding the research program, Mrs. de Groot of the research staff (phone: CY 3-5068) will be glad to talk to you.

Your school principal, _______ and the _______ Board of Education are cooperating whole-heartedly in this project to examine how children learn from visual presentations. Every effort will be put forth to make this a worthwhile experience for your child. Please sign below to indicate your approval and have your child return the slip to his homeroom teacher. Thank you.

Sincerely yours,

Willavene Wolf,
Division of Planning and Methodology
Bureau of Educational Research and Service

I hereby permit my child, _____ ______________, to participate in the research project "Educational Television and Perception."

(Signed) ______________________

APPENDIX B

OPTOMETRIC EXAMINATION SHEET FOR VISUAL SCREENING

Below are listed the various optometric tests conducted upon each subject. The subject listed in the example was rejected from use in the experiment.

Name: ____________ Age: 11 Sex: F

Address: ____________ Phone: ____________

Parent's Name: ____________

School: ____________

Visual Acuity: O.D. 20/50 O.S. 20/60 O.W. 20/50

Color Test: Negative

Retinoscopy: O.D.-1.25 = -0.25x60°

O.S.-1.75 sph

Ophthalomoscopy: Fundi normal-media clear

Phorias: 1 $^{\Delta}$ eso, no hyper.

Supression: None

Aniseikonia: None

Cyclorphoria: None

Stereopsis: 100"

APPENDIX C

THE CRITERION INSTRUMENTS: Visual Recognition (VR) and Visual Auditory Recall (VAR)

After each experimental session, the post-tests were administered to the subject. The two post-tests were based on visual recognition (VR) and understanding and recall of the visual and auditory portions of the films (VAR). A representative item from VR is presented below with the instructions which accompanied the tests. There were 21 such items in the test.

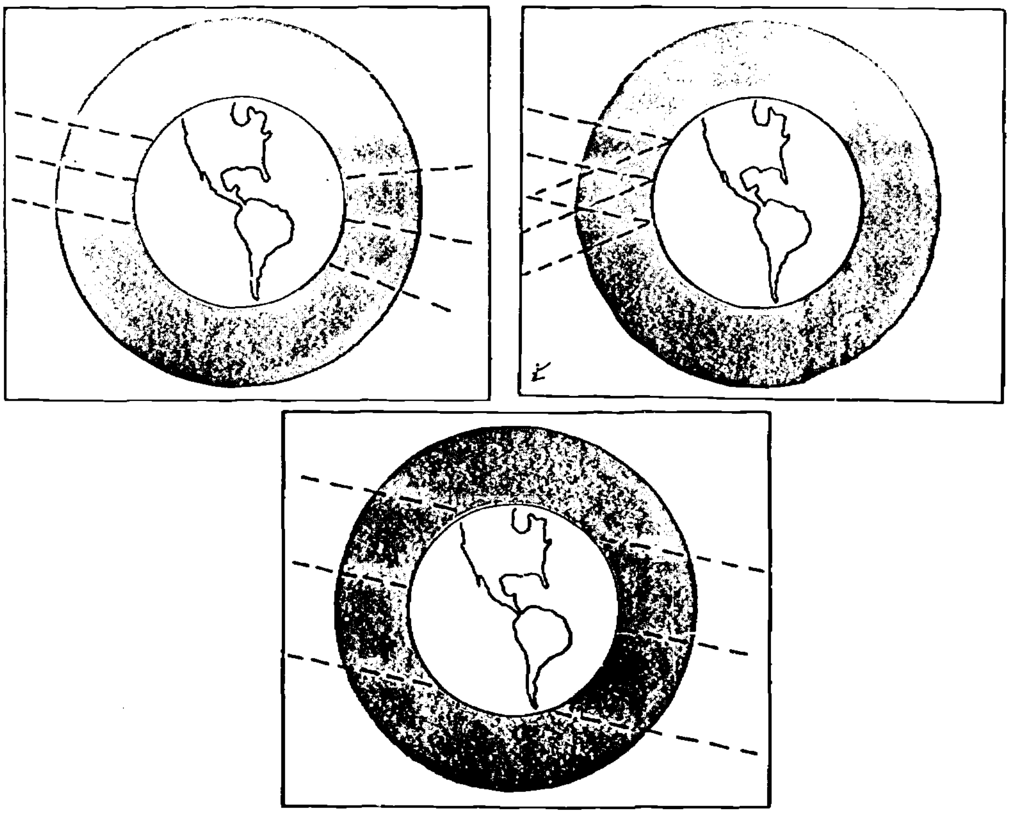


Figure 24 - A Representative Item from VR, Scene 4.2

Instructions on VR: This test will show some pictures like those you have just seen in the television lesson. You will see several pictures at the same time. Choose the one that is most like what you saw in the film. Make a mark on the answer sheet by blackening in the answer space for the correct picture. Do this for each group. You must make a choice for each question.

VAR

A true-false test was constructed to evaluate the recall and understanding based upon the visual and auditory portions of the films combined. This test is presented in its entirety following the instructions which accompanied it.

> Some of the following statements are true and some false. If the statement is true, circle the "T" at the right. If the statement is false, circle the "F". Do this for each question. Answer each question. Please go as fast as you can.

1. The atmosphere regulates the earth's temperature by absorbing the cold air. T F
2. Clouds reflect sunlight back into space during the day. T F
3. The reason the equator has more heat than the poles is because the sun's rays are more spread out at the equator. T F
4. Although the poles receive less heat from the sun, all of the heat is absorbed. T F
5. The motion of air keeps the equator from getting hotter and hotter. T F
6. Air masses do not mix gradually but at sharp boundaries. T F
7. Advancing "fronts" move from West to East. T F
8. At night clouds permit the earth's heat to pass right through to outer space. T F
9. One of the major costs of using sea water for crop irrigation is in purifying the water. T F
10. Less than one-half of the earth is covered with water. T F
11. The "water crisis" will probably never be solved unless there is co-operation among nations. T F
12. The earth's total supply of water is constantly decreasing. T F
13. In 1960 there were about six billion people on the earth. T F
14. The path of a single drop of water can be accurately followed. T F

15. The film indicates that only small countries should co-operate in utilizing the available water. T F

16. There is as much water now as there was 100 years ago. T F

17. Water is necessary for all forms of life. T F

18. In the "water cycle" one-quarter of the water is in the air. T F

19. An axis can be thought of as an imaginary line around which an object turns. T F

20. The horizontal axis of an airplane runs from wing to wing. T F

21. The vertical axis may be found by jabbing a pencil into the airplane and seeing where it comes out. T F

22. The axis line which runs from the nose of the airplane to the tail of the airplane is also called "pitch." T F

23. The "elevators" control the amount of rotation about the airplane's horizontal axis. T F

24. If the elevators of the airplane go down, the nose of the airplane goes up. T F

25. An airplane has three axes. T F

26. Water polluted by industry can be made reusable. T F

27. North America lies in a region of mild frontal activity. T F

28. Frontal waves help to cool the equator. T F

29. Rain is part of the water cycle. T F

30. All of the axes of an airplane cross at one point. T F

31. All of an airplane's movement is around one of the two axes lines which run through the airplane. T F

32. By the year 2000 there will be more than twice as many people as there were in 1900. T F

33. The warm and cold air around the earth mix gradually. T F

APPENDIX D

Kolmogorov-Smirnov - One Sample Test for Goodness of Fit

Visual Recognition (VR)

	6.5	7.5	8.5	9.5	10.5	11.5	12.5	13.5	14.5	15.5	16.5	17.5
F = NO. OF SUBJECTS CHOOSING RANK	2	2	0	3	2	2	3	4	4	2	1	1
FO(X) = THEOR. CUM. DIST. OF CHOICES	.0212	.0446	.0853	.1515	.2420	.3557	.4880	.6179	.7357	.8340	.9032	1.0000
$S_{N}(X)$ = CUM. DIST. OF OBSERVED CHOICES	.0769 2/26	.1539 4/26	.1539 4/26	.2692 7/26	.3462 9/26	.4231 11/26	.5385 14/26	.6923 18/26	.8462 22/26	.9231 24/26	.9615 25/26	1.0000 26/26
FO(X) - S_N (X)	.0557	.1093	[illegible]	.1177	.1042	[illegible]	.0505	.0744	.1105	.0891	.0583	.0000

N = 12

D = 0.1177 NS

Visual and Auditory Recognition (VAR)

	15.5	16.5	17.5	18.5	19.5	20.5	21.5	22.5	23.5	24.5	25.5	26.5	27.5	28.5	29.5	30.5	31.5	32.5	33.5
F = NO. OF SUBJECTS CHOOSING RANK	1	1	1	1	3	1	0	2	4	1	2	4	2	0	0	1	1	0	1
FO(X) = THEOR. CUM. DIST. OF CHOICES	[illegible]	[illegible]	[illegible]	.1000	.1492	.2011	.2743	.3520	.4304	.5279	[illegible]	[illegible]	[illegible]	.8315	.8810	[illegible]	[illegible]	[illegible]	[illegible]
$S_{N}(X)$ = CUM. DIST. OF OBSERVED CHOICES	1/26 [illegible]	2/26 [illegible]	3/26 .1154	[illegible]	7/26 [illegible]	8/26 .3077	8/26 .3077	10/26 [illegible]	14/26 [illegible]	15/26 .5769	17/26 [illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
FO(X) - S_N (X)	[illegible]	[illegible]	[illegible]	[illegible]	.1000	[illegible]	[illegible]	[illegible]	.1022	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0

N = 19

D = 0.1200 NS

APPENDIX E

TEST RESULTS (see Appendix C)

(VR)

Item No.	No. of Subjects Answering Correctly (N = 26)	Difficulty Value	High	Low	D* Discrimination Value
1	11	.42	71%	0	2.8
2	14	.54	86%	29%	1.4
3	21	.81	100%	57%	2.2
4	8	.31	57%	0	2.4
5	13	.50	71%	14%	1.7
6	14	.54	71%	43%	.8
7	16	.62	86%	43%	1.2
8	24	.92	100%	71%	1.7
9	21	.81	86%	57%	.9
10	13	.50	71%	14%	1.7
11	22	.85	100%	57%	2.1
12	14	.54	86%	29%	1.6
13	11	.42	43%	14%	.9
14	21	.81	100%	57%	2.2
15	23	.89	86%	100%	-1.2
16	20	.77	100%	71%	1.8
17	15	.58	86%	43%	1.3
18	17	.65	86%	29%	1.6
19	15	.58	57%	71%	- .5
20	7	.27	14%	29%	- .6
21	8	.31	43%	29%	.4

APPENDIX E (continued)

(VAR)

Item No.	No. of Subjects Answering Correctly (N = 26)	Difficulty Value	High	Low	D* Discrimination Value
1	19	.73	100%	43%	2.4
2	16	.62	86%	57%	.8
3	16	.62	86%	29%	1.6
4	17	.65	100%	29%	2.8
5	25	.96	86%	100%	-1.2
6	14	.54	100%	0	4.6
7	16	.62	86%	57%	.8
8	18	.69	100%	29%	2.8
9	21	.81	100%	71%	1.7
10	23	.89	100%	57%	2.2
11	23	.89	100%	71%	1.7
12	16	.62	71%	29%	1.0
13	15	.58	86%	57%	.9
14	20	.77	86%	43%	1.2
15	24	.92	100%	71%	1.8
16	20	.77	86%	71%	.5
17	26	1.00	100%	100%	0
18	9	.35	43%	14%	.8
19	25	.96	100%	100%	0
20	17	.65	100%	43%	2.5
21	20	.77	100%	29%	2.9
22	14	.54	71%	29%	1.0
23	17	.65	57%	71%	- .5
24	10	.39	57%	14%	1.2
25	20	.77	100%	43%	2.5
26	23	.89	100%	86%	1.3
27	15	.58	71%	29%	1.0
28	10	.39	43%	71%	- .8
29	25	.96	100%	86%	1.3
30	23	.89	100%	86%	1.3
31	10	.39	86%	0	3.3
32	23	.89	100%	100%	0
33	15	.58	71%	43%	.7

*D = Lawshe's technique in Guion Personnel Testing.

APPENDIX F

SUBJECT DATA

	Subject Number	IQ	Age in Months	VR	VAR
High IQ, High Age	1	131	204	15	25
	2	123	195	18	26
	3	121	203	15	28
High IQ, Middle Age	4	140	158	8	17
	5	129	161	12	27
	6	127	164	11	26
High IQ, Low Age	7	138	143	13	32
	8	127	143	15	26
	9	120	138	14	32
Middle IQ, High Age	10	114	196	16	33
	11	111	201	11	24
	12	105	202	13	24
Middle IQ, Middle Age	13	111	164	14	28
	14	108	161	12	21
	15	107	160	10	19
Middle IQ, Low Age	16	108	144	17	24
	17	108	144	7	20
	18	106	141	15	24
Low IQ, High Age	19	99	198	10	27
	20	93	195	10	27
	21	92	197	14	18
Low IQ, Middle Age	22	99	165	13	23
	23	96	159	7	20
	24	93	162	8	16
Low IQ, Low Age	25	96	141	14	20
	26	90	150	16	23

SCENARIO*

ORIGIN OF WEATHER (Scenes 2.01 - 9.01)

SCENE NO.	FRAME NO.	VISUAL	EXPLANATION	AUDITORY
			Calibration Target 1 - 282	
			SECTION I: Scenes 2.01 - 3.52; Frames 1 - 2218	
2.01	1-72	Animation sequence; earth's atmosphere, sun's rays and clouds	Almost all light in this scene is on the clouds (center of screen). Top half of screen is grey, bottom is dark.	
2.10	73-125	Static shot of earth	Background is black. World at center right is lighter on left side. Slight light ring around globe. North and South America are darker (grey).	We will understand
2.20	126-222	Earth shrinks in size	Lighting is the same as 2.10, but as the earth shrinks, black background becomes larger. Earth, now smaller, stands out even more. Right side of earth is shaded darker, while atmosphere is lighter on right side.	more easily how this envelope of atmosphere protects us
2.21	223-262	Static shot of small earth	Right side of earth is shaded darker. Atmosphere is lighter on right side.	if we show it much
2.30	263-440	Exaggerated atmosphere	Earth is at center--light with dark continents. Large light circles around earth, leaving the rest dark.	exaggerated in size.

*The Scenario was prepared as a working copy for project use. The personnel were thoroughly familiar with the scenes; therefore, the Scenario merely served as an aid in recall. It is included for the reader who wishes to scrutinize the films.

SCENE NO.	FRAME NO.	VISUAL	EXPLANATION	AUDITORY
			Left portion of earth is still lighter. Small ring is still there also. Faint, barely visible rays appear (slowly from 263-286).	
2.40	441-503	Light rays appear	Light rays (dash lines) on left, moving from left to right. Dark background. Globe in center with light atmosphere circle around it.	Of the sunlight that reaches the atmosphere,
2.50	504-588	Close-up of model	Light rays on left. Globe moves forward and to the right until there is no dark background on right. Atmosphere light circle around globe now fills right top and right bottom of screen. Light rays on left. Light rays continue to move left to right. Dark background is on left, globe the same.	only some penetrates to reach the earth.
2.60	589-957	Sunlight rays penetrate atmosphere	Objects remain the same. Light rays continue left to right and half of them penetrate the atmosphere all the way to the globe. The other four rays penetrate only to the atmosphere.	Part of the sun's energy is absorbed by the gases and water vapor in the atmosphere. A part of it is reflected back to space
2.70	958-1136	Rays reflected by clouds	Light rays continue to penetrate left to right. Clouds appear on left of globe top middle and bottom middle. Rays move from the two clouds right to left, top one rises, bottom one lowers. Other lighting is the same as 2.50 and 2.60.	by clouds. The sea and land also reflect some of the sunlight

SCENE NO.	FRAME NO.	VISUAL	EXPLANATION	AUDITORY
2.80	1137-1275	Rays reflected by land	All same as 2.7 except light rays move from globe on right top and bottom away from globe, left to right. Top one rises, bottom one lowers.	back into space. The atmosphere not only helps
2.90	1276-1322	Rays disappear	All light rays disappear leaving globe at right of screen surrounded by light atmosphere circle. Globe is almost at right edge of screen so light circle on that side is cut off. Left side of screen is black. Lines begin disappearing at 1258 and are gone at 1276. The rest is static.	to protect the earth from too much heat
(3.0	1323-2220	Animation sequence, earth's atmosphere and clouds at night.)		
3.10	1323-1431	Model moves from right to left	Model moves from right to left all the way across the screen. Earth is encircled by light atmosphere. As it moves, the light atmosphere on right is shown totally. Then, as the globe moves toward left of the screen, the light atmosphere on the left is lost as globe's edge reaches left side of the screen. Finally, left side of globe is off screen (by 1432) and movement stops. Left side of globe meets left side of screen at 1403.	each day; but also helps to protect the planet each night.
3.11	1432-1484		Globe remains stationary as above.	As we have
3.12	1485-1505		Globe remains stationary at left but	already seen, if

SCENE NO.	FRAME NO.	VISUAL	EXPLANATION	AUDITORY
			atmosphere on right, bottom, and top slowly disappears.	
3.21	1506-1532	Rays appear and atmosphere disappears	Globe remains stationary at left. Lighting is the same as in end of 3.12. No atmosphere, no rays.	there were no
3.22	1533-1713	Rays appear	Rays appear on right of globe, coming from center right moving left to right. Globe remains static.	atmosphere, heat would be lost each night. But the atmosphere and
3.31	1714-1736		Clouds and small rays appear on right side of globe (about center of screen).	especially clouds
3.32	1737-2050	Rays disappear; atmosphere and clouds appear	Light atmosphere forms around globe and rays on right slowly disappear until they are gone at 1737. Now the globe is stationary at the left with the atmosphere around top. Clouds form on the right within atmosphere. Small rays move from clouds and back. Globe is stationary at the left. Atmosphere around globe. Clouds and small rays move both ways from clouds to land. Small rays and clouds begin to disappear and are gone at 2050.	reflect much of the heat back to the Earth, helping to even out the difference between day and night temperatures.

SCENE NO.	FRAME NO.	VISUAL	EXPLANATION	AUDITORY
3.40	2051-2143	Clouds and rays disappear	Globe is at the left as before. No clouds or rays, only atmosphere around globe top, bottom and right. Right side of screen is dark.	And there is another far more important temperature difference
3.51	2144-2173	Montage to Earth on right	New globe begins to form on right while the globe on the left begins to disappear. Both globes are visible with lighting atmosphere around each, especially around the globe on the right.	which might be
3.52	2174-2218		Only the globe on the right remains. Atmosphere is around it--top, bottom and and left. The left side of screen is dark.	evened out.
			SECTION II: Scenes 3.60 - 5.32; Frames 1 - 1529	
3.60	1-74	Cut to model in center	Cut to model in center--globe with light atmosphere around it. Right side of globe is darker than left side. Rest of screen is dark. There are some light streaks in left atmosphere.	The equator is continually
(4.0	75-864	Animation sequence; distribution of surplus heat)		
4.10	75-242	Light rays of equator	Light rays begin to appear on left side of globe at middle. They move from right to left within atmosphere, but left to right outside atmosphere. Rays extend	getting large amounts of heat. In fact, measurements show it gets

SCENE NO.	FRAME NO.	VISUAL	EXPLANATION	AUDITORY
			from left side of screen to the globe by 85.	more heat during
			Main scene same as 85. Rays move left to right.	
4.20	243-389	Re-radiation of rays	Three rays begin to appear within atmosphere on right of globe, visible by 251. Rays on right move left to right but stay within atmosphere. Rays on left of globe continue moving left to right.	the day, then it re-radiates to space at night.
4.31	390-436	Equator rays disappear; pole rays appear	One ray at top of globe and one at bottom appear at left. Now five rays on left, moving left to right into globe and small rays on right within atmosphere continue left to right. Middle rays begin to disappear, and are completely gone at 436. Small rays on right also begin to fade and disappear at 436.	
4.32	437-566		Globe in center, atmosphere around it. Two rays--1 at top, other at bottom left of globe--move left to right.	
4.40	567-865	Re-radiation at poles	Three rays, each begins at top and bottom of globe. Visible by 573. Rays at top and bottom begin to move toward and reach their respective screen edges. Each continues to move in that direction. Rays on left remain.	

SCENE NO.	FRAME NO.	VISUAL	EXPLANATION	AUDITORY
(5.0	866-1528	Animation sequence: uneven heating of Earth and air currents.)		
5.10	866-903	Rays at equator; Re-radiation at poles	Three rays appear at middle left of globe. Top and bottom left rays disappear. Rays at top and bottom. Three rays at middle left moving left to right.	From this, one
5.21	904-936	Bands about equator	Dark band forms across middle of globe. Rest is the same.	might
5.22	937-989		Band separates into two. Clearly visible at 945. Rest is the same.	expect that
5.23	990-1230		Scene continues (Top and bottom, and left rays).	the equator would grow hotter and hotter and the poles grow steadily colder, but this doesn't happen because the uneven heating of the earth by the sun sets
(5.30	1231-1529	Air currents)		
5.31	1231-1254		Light bands begin to appear within atmosphere. Clearly visible at 1254.	the air
5.32	1255-1529		Bands are moving, rest the same, except that the atmosphere is no longer circular but a little flat on each side.	in endless motion. As the air moves, it carries surplus

SCENE NO.	FRAME NO.	VISUAL	EXPLANATION	AUDITORY
				heat from the equator to the poles, and cold air from the poles toward the equator.

Calibration Target

<u>SECTION III</u>: Scenes 6.10 - 6.80; Frames 1 - 1268

(6.0	0-1268 Animation sequence: diagram-distribution of warm and cold air on Earth)			
6.10	1-74	Schematic of Earth and atmosphere		A simple diagram which
6.20	75-189	Dark band at equator	Dark band forms across middle of small circle .	shows warm air at the equator and cold air near the poles--
6.30	190-456	Shading into poles	Shading at the poles.	but scientists have learned that these cold and warm air masses do not just mix gradually. These air masses meet

SCENE NO.	FRAME NO.	VISUAL	EXPLANATION	AUDITORY
6.40	457-591	Cut: Frontal waves	Dark irregular patterns representing frontal activities form across center of small globe. New shaped pattern.	sharply at wave-like boundaries called "fronts".
6.50	592-753	Cut: close-up, frontal waves move right	Cut to close-up of small globe with pattern. Pattern moves left to right. Background is light. Rest of globe is grey.	The warm and cold air do not mix gently. The fronts are like ever-changing
6.60	754-856	"Dynamic" fronts	Pattern continues to move left to right but pieces fly off and the pattern convulses.	battlelines in the endless war of heat exchange.
6.70	857-953	Zoom into Northern Hemisphere	Pattern continues to move left to right. Camera zooms in on globe. The bottom is slowly cut off until the only background is at top.	
6.80	954-1268	North America appears	North America appears at top inside globe. Pattern continues to move left to right. North America is outlined in light.	North America lies in the path of this intense frontal activity, and the fronts produce rapidly changing weather conditions. By following one of these waves of cold air

SCENE NO.	FRAME NO.	VISUAL	EXPLANATION	AUDITORY
		SECTION IV: Scenes 7.10 - 9.01		
(7.0	1-1883	Animation sequence: formation of clouds at fronts)		
7.10	1-175	Side view of advancing cold front; moves to right starting at frame 12.	Scene begins with large light area representing a cold front at the left bottom and city at right bottom. At the very bottom (1-2") is a dark line (land) all the way across the screen. The front moves from left to right toward the city. The rest of the scene is fairly dark except just above the front and city. This area is a little lighter than the rest. Front gets larger as it moves across.	and looking at it in a side view as it moves eastward, we can see how weather is produced.
7.20	176-333	"City" moves to left	Scene lighting is the same. Front stops moving about the center of the screen. City and land begin to move right to left toward front, meeting it at frame 236. The city continues going into the front.	(250) The advancing cold air, known as a cold front
(7.30	334-544	Arrows successively appear)		
7.31	334-477		City and land continue to move right to left inside of front. Large arrow appears inside right of front.	is more dense and heavy than the warm, so it flows along the ground and
7.32	478-510		City continues to move, 2nd arrow appears at (478) outside right of front. 1st arrow remains.	pushes warmer, moister air

SCENE NO.	FRAME	VISUAL	EXPLANATION	AUDITORY
7.33	511-544		City and land continue to move. 1st and 2nd arrows remain but 3rd arrow appears (5") just above 2nd arrow--outside, top, right of front.	upward
7.40	545-592	Air currents	City moves off screen (560). Arc lines form (545) around 2nd and 3rd arrows. Arrows begin to disappear (577-591). By 592 all 3 arrows are gone, leaving the front and the arc lines on its right. Land continues to move.	out of the way.
(7.50	593-806	Arrows disappear)		
7.51	593-628		Arc lines remain stationary but appear to be moving toward top of screen. Land continues to move right to left.	
7.52	629-689		Smaller city appears on land, moving right to left at right side of screen. City is in full view by 680. Rest of scene is the same as 7.51.	
7.53	690-806		City continues to move right to left, gets to right middle of screen. Rest of scene is the same as 7.51.	As the warm air rises, it cools and its
(7.60	807-1029	Cloud formation)		
7.61	807-871		Clouds form at middle bottom of arc lines just above the city, but a little left. City meets front at 849. Rest of scene is same as 7.51.	moisture condenses into clouds,

SCENE NO.	FRAME NO.	VISUAL	EXPLANATION	AUDITORY
7.62	872-941		Clouds form at middle and top of arc lines just above other cloud. City enters front (906). Rest of scene is the same as 7.51.	sometimes
7.63	942-1029		Clouds form horizontally (938-942) above arc lines and the arc lines begin to disappear. (Gone at 1022.) City continues to move right to left (about 3" from left of screen at 1029). Rest of scene is the same as 7.51.	into towering cumulo-nimbus clouds which, as they
7.70	1030-1192	Currents disappear	Arc Lines disappear. Scene is the same as in 7.63. City and land continue to move right to left. City touches left side of screen at 1096. City is off screen at 1141.	sail across the land, may herald a variety of weather disturbances.
7.80	1193-1245	Thunderstorm	Land continues to move right to left. In 1193 lightning comes straight down the middle of the cloud formation and disappears at 1195. 2nd lightning shows in 1196 at the bottom and disappears at 1198. 3rd lightning shows at 1199, like 2nd lightning, moves off at 1201. 4th lightning shows at 1201, disappears at 1202. At 1214 the rain falls--black, vertical lines under the clouds, continuing to 1244. In 1244 a view of land and houses appears across bottom of screen.	(Sound of thunder and lightning.)

SCENE NO.	FRAME NO.	VISUAL	EXPLANATION	AUDITORY
(8.0 Rainstorm)	1246-1741	Actual photos:		
8.10	1246-1327	Puddle of water	Horizontal splashes roll from bottom of screen to top. The picture gives the impression of looking down on a puddle. The "waves" are darker than the rest of the water and the bottom left of the screen has a dark triangle.	(Splashing sounds)
8.20	1328-1410	Roof	Raindrops fall down vertically from the top of screen. There are a number of raindrops across the screen. Background is light, raindrops dark. A roof is really not visible as the drops come out of the top of the screen.	(Sounds of rain falling)
8.30	1411-1554	Field scene	Across the bottom of the screen are trees. They are dark and extend up two to three inches. The rest of the scene is filled with clouds. One at center and one at top left are darker than the rest. There are no moving objects. One tree stands up at middle (bottom of screen). Also, there are some obvious trees at night (bottom of screen).	As the disturbance moves on, clouds break up and the sun be-begins to emerge
8.40	1555-1656	Clouds	The bottom of the screen is dark. At the left bottom is a dark cloud. The rest of the clouds are light and mostly in the right and middle of the screen. The top and rest of the scene background is darker than the light clouds but not as dark as the bottom and the dark cloud at left bottom. The scene is static.	marking the end of one tiny weather disturbance

SCENE NO.	FRAME NO.	VISUAL	EXPLANATION	AUDITORY
8.50	1657-1742	Sun	This scene is also stationary. The sun is a light globe approximately in the center of the screen but a little left and high. In the lower, right corner there is a light cloud. The rest of the screen is darker (rather greyish).	in an endless series of weather events.

PILOTING AND CONTROL OF AN AIRPLANE

Calibration Target 1 - 287

SECTION V: Scenes 10.1 - 11.63; Frames 1 - 2080

SCENE NO.	FRAME NO.	VISUAL	EXPLANATION	AUDITORY
(10.0	1-168	Narrator behind table, plane model on stand, distractors)		
10.01	1-40	Black screen		
10.10	41-84	Narrator behind table	Narrator stands in the middle. A white airplane stands out from his dark suit at the middle bottom of screen. Another airplane hangs on the wall in the upper righthand corner with an airplane and other objects at left and lower left-hand corner. The Narrator's mouth is moving as he is talking. Right hand (left side) moves up at frame 52-60. At frame 56 he begins to move from left to right. His right hand moves slightly to the right while his left arm and	(Mouth moving but no sound)

SCENE NO.	FRAME NO.	VISUAL	EXPLANATION	AUDITORY
			hand much more noticeably move in the same direction.	
10.20	85-123	Narrator picks up pencil	Background same. Narrator's body turns slightly back from screen. Left hand picks up pencil from table and moves toward narrator's stomach and right hand (center-bottom of screen). At frame 64 pencil is transferred to right hand and back to left hand at frame 80.	
10.30	124-168	Narrator indicates horizontal axis	Background same. Body of narrator slowly turns back until facing forward (left on screen). Right hand moves down and then left until it rests on left (on screen) wing of airplane. Left hand (right of screen) stays in about the same place but has pencil in it and moves slightly.	If I were to take ... (Cut on words)
(11.0 and hands)	169-2080	Close-up of model		
11.11	169-224	Close-up of model	169 is a blur. 170 is first actual shot. Narrator's body from neck to bottom of suit coat is seen at right of screen. Left side is grey. Narrator's right hand (left side) is on left side of plane and his left hand is on right side with pencil in it. Pencil hand moves up screen to back of airplane.	An airplane has three axes that it works from.
11.12	225-299		Everything same except pencil hand moves back down to front of airplane at right side of wing.	If I were to take

SCENE NO.	FRAME NO.	VISUAL	EXPLANATION	AUDITORY
11.13	300-320		Everything same except pencil hand moves left to right toward right side of screen until almost off at frame 280.	and jab
11.14	321-408		Everything same except pencil hand moves back right to left, to right side of wing. Meanwhile right hand on left side of airplane is moving slightly.	a pencil through
11.15	409-709		Everything same except both hands on either side of airplane, moving slightly.	this wing so that it came out the other side, and if I were to hold the pencil, and if that airplane were balanced, we would have found the horizontal axis.
11.16	710-735		All same except left hand jumps up about 1-2 inches (on right side of screen).	There is
11.17	736-751		All same except left hand moves up screen to back of plane. Right hand moves down to center front of plane (about middle bottom of screen). Body moves back from airplane and right.	another
11.18	752-787		All same except left hand (right side) moves down slightly then up and around	

SCENE NO.	FRAME NO.	VISUAL	EXPLANATION	AUDITORY
			the back of plane right to left until reaching left side back of airplane. Right hand moves down and off screen.	line that
11.19	788-816		All same except left hand moves down screen on left side of airplane until reaching wing.	runs from the nose of the
11.20	817-844		All same except left hand moves back up left side to back of plane. Right hand moves up onto screen to front center of airplane where there is a handle on the bottom.	airplane
11.21	845-875	Turns model - side view	All same except right hand turns air-plane left to right until it is side-ways. Left hand follows back of airplane around.	back to the tail
11.22	876-924		Same as 11.21 except left hand goes up around back of airplane right to left. Right hand (on left of screen) moves up to meet left hand (moving left to right) until joining left hand.	of the airplane. If I were to do
11.23	925-946		All same, except pencil is transferred to right hand and hands move in opposite directions to outside and bottom of screen until off screen.	the same thing again
11.24	947-997		Narrator leans left. Right hand, left side, comes back on screen to point to front of airplane on far left side and bottom of screen.	and that is jab the pencil in

SCENE NO.	FRAME NO.	VISUAL	EXPLANATION	AUDITORY
11.25	998-1031		Left hand comes up to back of airplane on right side of screen.	so that
11.26	1032-1082		Right hand moves on left side of screen left to right and down to wing and off bottom of screen. Left hand (right side) holds on to back of airplane.	it came out back here
11.27	1083-1301		Right hand moves back up left side of screen to front of plane on left side. Left hand is still on right side of airplane. One hand is now on each side of airplane and the hands move slightly up and down.	and if we could hold those two points and the plane were balanced we would have the longitudinal or the long axes.
11.28	1302-1372		Both hands move down and then up on the far side (Narrator's side) of plane until right hand is on left side at nose of plane and left hand is at right middle about 1-2 inches above plane.	Now you know
11.31	1373-1602	Uses hands to indicate crossing of axes	Right hand comes across left to right along topside of plane and left hand goes forward until they meet and cross at frames 1371-1562. Hands stay together from 1381-1562.	that if I put a line this way and a line this way (cross - 1371) someplace they are going to cross, aren't they? And, at that point where they cross,

SCENE NO.	FRAME NO.	VISUAL	EXPLANATION	AUDITORY
11.32	1605-1640		Right hand (on left side) moves away (left) and up from plane and from other hand and then begins to come back over to right at frame 1600.	
11.40	1641-1800	Points out vertical axis	Narrator's right hand is on left middle side of screen with pencil in it. He raises it up and down to wing and fuselage of model airplane. Left hand rests on top of airplane (middle of screen) until frame 1729 when it moves up. At this time (1739) right hand turns pencil up and left hand takes hold of other end of pencil.	we have another axis, an up-and-down axis or a vertical axis.
11.50	1801-1879	Points out longitudinal axis	Left hand (right side) takes hold of pencil. Right hand moves down around front of airplane on far left of screen and comes to rest under airplane at about frame 1800. Meanwhile, left hand moves right to left with pencil in it getting to front of airplane at about frame 1800. From 1800-1825 left hand sweeps along top of airplane left to right.	So we have our, we have our longitudinal axis;
11.61	1880-1910	Turns model	Left hand moves up and away in back and right hand turns model front left to right (back moves right to left) until you get a front view of the plane.	
11.62	1911-1934		Left hand (right side of screen) moves forward down fuselage of model airplane.	we have our horizontal axis;

SCENE NO.	FRAME NO.	VISUAL	EXPLANATION	AUDITORY
11.63	1935-2080		From 1895-1913 left hand goes out and in (left to right then right to left) toward plane. Then it moves back up fuselage (1914-1930) and crosses over at the tail end of the airplane (1930-1960) to the other side (right to left). It then moves forward to front of plane and quickly back to rear of plane. At last it makes a quick jog left to right (2033-2044) then there is a new shot.	and where they cross we have the vertical axis. I want you to look at

SECTION VI: Scenes 12.01 - 12.20; Frames 1 - 2003

SCENE NO.	FRAME NO.	VISUAL	EXPLANATION	AUDITORY
12.01	1-369	Schematic of airplane	Crossed lines form an X on screen. Back part of fuselage is dark (left, upper, middle side of screen). Right wing (left, bottom of screen) also has a dark patch. Black "border" around white background with plane in middle. "Writing" at right side center.	a diagram (that) we have here. Notice the dotted lines. They all cross at one place, don't they. This is the whole, this is the one balance point for the whole airplane, or what we call the center of gravity.
(13.0 behind table)	370-486	Narrator		
13.01	370-436		Same general description as 10.1 Narrator's left hand (right side) moves down	When we talk about

SCENE NO.	FRAME NO.	VISUAL	EXPLANATION	AUDITORY
			the plane and under left wing (right side). Right hand (left side) comes up to nose of airplane. At 395-436, Narrator shifts right to left.	
13.02	437-487		Narrator turns plane nose right to left and airplane tail left to right so that it turns around sideways.	an airplane
(14.0 of "pitch")	488-901	Demonstration		
14.10	488-517	Close-up of model	Narrator tilts plane. At 494-517 right hand (left side) moves from stand under middle of plane (middle bottom of screen) right to left to nose of plane on left middle of screen.	revolving
14.11	518-578		Narrator's body moves right to left leaning. Left hand (right side) moves down left to right, then back up behind airplane and right to left to middle of airplane and crosses over toward front of screen to wing.	around the axis that goes
14.12	579-640		Narrator moves left hand (middle of screen) from wing toward his body, reaching body at 611. Then he moves left hand from left to right and down to back end of plane in 611-640.	through the wing,

SCENE NO.	FRAME NO.	VISUAL	EXPLANATION	AUDITORY
14.20	641-781	Narrator rotates model about horizontal axis	Narrator tilts airplane up and down, backward and forward.	if it revolves around that or works around that, we have what we call "pitch".
14.30	782-901	Super: pitch	Tilting continues, but the word "pitch" is superimposed at bottom middle of screen, in white, small-case letters.	The airplane works up and down like this and that's what we call "pitch".
(15.0 another model)	902-1211	Narrator gets	Narrator in center of screen. Original white airplane is now at left side of screen.	
15.10	902-927	Narrator is behind table	Narrator is behind table in the room as at the beginning of the film. He turns left to right on the screen and heads across the room in that direction.	
15.20	928-987	Narrator reaches for object	Narrator continues in that direction and takes another model on right side of screen with left hand. On left upper part of screen are two models on the wall.	
15.21	988-1118		Narrator brings model and body back right to left (model in left hand--right side of screen) until at frame 1092, right hand also takes hold of model. Then camera moves, taking in more of picture on left side and first model there on stand.	

SCENE NO.	FRAME NO.	VISUAL	EXPLANATION	AUDITORY
15.30	1119-1211	Narrator places object near, as if to place it on table. (Note: he never places object on table)	Note: the "object" is composed of two parts--the stand and the tail. Narrator sets the stand down, 1117, then removes the tail from it, 1119. Camera continues to move right to left. At 1129-1178 left hand (right side) moves away from model left to right until reaching right side of screen at 1176. Then the left hand (right side) moves right to left again toward model.	Now the air, or the wind, is coming from this way.
(16.0 control pitch)	1212-2003	How elevators		
16.10	1212-1325	Close-up of model and hands	Cut to close-up of hands, holding new model (a tail) at about the middle of the screen). Portion of body is shown--dark suit. Background is grey. Hands and tail are very white. Left hand (right of screen) moves along tail from right to left. Hands move slightly around tail and tail moves. Grey table at bottom of screen. Table has shiny top. White paper at lower left corner of screen.	And this is the model of what our elevators look like.
16.11	1326-1373		Hands move down and away from tail and come to rest on table. Tail remains suspended (on clear stand) but tilts up and down.	Now, if I have the elevators straight
16.12	1374-1406		Right hand (left side) lifts off table coming up to left above tail (pointing at 1385). Tail still is tilting.	

SCENE NO.	FRAME NO.	VISUAL	EXPLANATION	AUDITORY
16.13	1407-1467		Right hand goes back down to table reaching it at 1419. Then both hands come up above and on back screen of tail and fingers hit tail to make it tilt even more.	you see, the board sort of balances,
16.14	1468-1520		Hands come back down to table reaching it at 1478. Tail continues to tilt up and down. Hands come back up to tail, grasping it at 1558, scene still shifting.	doesn't it!
16.15	1521-1566		Between 1540 and 1564, camera shifts from right to left and back again. Camera is closing in.	But when I
16.20	1567-1684	Hands bend tail	Right hand (left side) bends front of left end of tail down 1574-1634, then bends it again from 1635-1684.	move the elevator down, now watch what happens.... now watch
16.21	1685-1716		Right hand comes up above tail and rests on its top left end just beside the bend.	what happens to
16.22	1717-1764		R'ght hand moves around bend finally grasping around it.	this part on this side of the pivot point.
16.23	1765-1805		Left hand (right side) moves left to right end of tail and grasps it at 1805. Right hand stays.	And watch to
16.24	1806-1871		Both hands hold tail until 1823, then	see what happens

SCENE NO.	FRAME NO.	VISUAL	EXPLANATION	AUDITORY
			left hand (right side) lets go and grasps again (1836-1842). This is repeated at 1843-1849, 1850-1854 and 1855-1861. The right hand then stays.	to this part on this side of the pivot point,
16.25	1872-1922		Left hand (right side) lets go of tail and moves down to rest on table (1872-1884). Left hand remains on table. Right hand (left side) remains around bend.	when I let go of it.
16.30	1923-2003	Model tilts	Right hand (left side) lets go of tail and moves to left side and partially off screen (1923-1940). Right hand now comes down to table (1940-1954). Right hand remains resting on table until frame 2003 at end of Section. When right hand (left side) leaves tail (1923) the tail begins to tilt up and down and does so until the end. Left hand (right side) remains on table motionless all the way through 16.30.	Now watch..see?

COMMERCIAL

Calibration Target (Frames 1 - 286)
Black screen (Frames 287-317)

SECTION VII: Scenes 17.10 - 17.60 Frames 587-1459

Selected Scenes

17.10	587-671	Ajax box.	Box faces forward - static.	

SCENE NO.	FRAME NO.	VISUAL	EXPLANATION	AUDITORY
17.20	676-681	Ajax box	Box moves and turns sideways right to left.	
17.30	682-759	Ajax box	Words on right, box on left, both static.	
17.40	1329-1377	Ajax box	Box faces forward--static.	
17.50	1378-1387	Ajax box.	Box moves and turns sideways right to left.	
17.60	1388-1459	Ajax box.	Words on right, box on left--both static.	

WATER

SECTION VIII: Scenes 18.01 - 25.10 Frames 1 - 1751

18.01	1-69	Title sequence	Black screen.	
18.10	70-185	Single drop of water	Single drop of water hangs in middle of screen. Background is dark.	Music
18.20	186-204	Background moves vertically	Background moves vertically.	
18.30	205-468	Drop changes shape and grows	Drop changes shape. At about 300 center begins to enlarge and grows circular until at about 429-468 it is a large round bubble taking up the center of the screen.	Music

SCENE NO.	FRAME NO.	VISUAL	EXPLANATION	AUDITORY
18.40	469-547	Splash	At frame 469 there is a white bubble at center, more towards the top. In frame 470 the bubble bursts and continues to burst through 534-547. The screen is rather dark.	
18.50	548-708	Reflection on water and title	White lines cross screen diagonally. Word "water" begins to come on diagonally across white lines at 644 and is visible at 659. Darkness at 683-708.	
19.0	709-790	Wavy lines, horizontal	Then white lines come in from both sides of screen (710) with small lines first. These fade out at 756 and big lines are left (still moving) until 790.	
(20.0 Animation: sky)				
20.10	791-878	Smokey field	791-800 is grey. Then greyish clouds form. Camera moves, "zooms", in on them. Clouds becomes darker; splotches of black on screen.	Music
20.20	879-932	Snow flakes	Little white specks appear all over screen in front of clouds and fall downward from top to bottom of screen. At 888 some of these become large crystals and all continue falling until	
20.30	933-980	Droplets	the specks become drops and the crystals disappear at about 949. Rest same. Clouds visible in background.	
20.40	981-1023	Clouds	White horizontal lines appear in center of screen. Drops still falling. At 1002	

SCENE NO.	FRAME NO.	VISUAL	EXPLANATION	AUDITORY
			drops turn to straight lines falling down. Clouds become more visible but drops continue to fall.	
21.01	1024-1155	Mountain--zoom in	1024-1040. Dark mountain appears in background. 1040-1155 camera zooms in on mountain. ("Zoom in" consists of the mountain growing larger until only the top of it shows at 1155.) Drops disappear at 1050. Clouds remain around mountain. Mountain is at center of screen.	
22.01	1156-1226	Growing tree.	1156-1164 is static of ground. Ground is dark across bottom of screen with a mound on each side. Rest is light. Grey at top. At 1165 tree begins to grow in middle from bottom to top. Tree grows from 1164-1226.	
22.10	1227-1375		Static shot of tree and ground. (About 1248, leaves start appearing on tree.)	Water, essential to all life, always,
23.01	1376-1408	Cells and water diffusion	Round light circles start appearing across top of screen cutting off top of tree. Then rest of the screen is covered until all is covered and tree is gone.	always on the move. Water
23.10	1409-1489		At 1409 a new tree with white lines begins to grow, superimposed on the dark cells and continues to grow till 1489.	inside of us.

SCENE NO.	FRAME NO.	VISUAL	EXPLANATION	AUDITORY
23.20	1490-1539		Static shot of new tree, superimposed over cells. Bubbles start changing about 1528.	
24.01	1540-1629	Relief map and rivers	1540-1559 - Begins with tree in center and cells begin to disappear. Then tree begins to disappear and mountain ranges form with a valley between. All are formed at 1555. Water is at bottom. This remains static until 1560, then little rivers begin to form in the mountain moving from top to bottom of screen and toward the center (the valley). At 1614 they meet in the center of the valley and a large river flows down and into the water at the bottom of the screen (splash down is on frame 1622-1629).	Water all about us. Water
24.10	1630-1680		Static shot of mountains, rivers, and large river that meets the water at the bottom of screen.	crosses all barriers.
25.01	1681-1728	Flags	At 1681 there is a blank white screen. A flag begins to appear at 1683. Banner on sticks rises up screen (from bottom to center) stopping its movement at 1700. From 1700-1728 it is motionless.	
25.10	1729-1751		At 1729 first flag disappears. At 1730 new one comes up from other side (1730-1748). Remains stationary from 1748-1751.	

SCENE NO.	FRAME NO.	VISUAL	EXPLANATION	AUDITORY
			Calibration target (289 frames). Blank screen (29 frames).	

SECTION IX: Scenes 26.01 - 33.10, Frames 1 - 1507)

SCENE NO.	FRAME NO.	VISUAL	EXPLANATION	AUDITORY
(26.0	1-262	Animation of water cycle)		
26.01	1-28	Black screen		
26.10	29-131	Split screen; elements on right	Left side is a light color. Background of right side is grey. A light cloud is at top. From it a mass of rain falls into a catcher, about 2 inches from bottom of screen. The catcher begins about half full, then fills to near top with the rain. Rain stops falling about frame 96.	Getting the right amount of water to the
26.20	132-262	Split screen elements on right and left	Left side becomes water background (like in a lake) with a miniature mountain (dark) in the middle. The sun (dark with light rays) is above the mountain about 3/4 up the screen. Water flows out of the bottom of the container right to left to water on left side of screen and then up toward the rock.	place where it is needed at the right time is a complicated business. Methods of
(27.0	263-450	Direction of movement of water in cycle)		

SCENE NO.	FRAME NO.	VISUAL	EXPLANATION	AUDITORY
27.10	263-282		White line appears across screen.	measuring the
27.11	283-311		New lines appear (245) on left side and (at 274-275) container disappears on right side. Scene remains to 283. At 278 scene is no longer split. Background all grey, white lines for diagram.	movement of water are becoming
27.20	312-329	Arrows appear	Now the whole process of water from cloud to lines to water to cloud is shown. Arrow (black) forms vertically top to bottom on right side (284-295)	more precise.
27.21	330-346		Same general picture but new lines (black arrows) form. One on right grows right to left (302-313). Water process continues.	
27.22	347-365		Arrow forms on left side of screen moving (319-331) vertically bottom to top of screen. Water process continues.	
27.23	366-391		Arrow forms (338-349) across top of screen. Rest remains and water process continues.	
27.24	392-415		Scene changes. Artist employs lines to make changes. Ridgy lines on right become mountains. All arrows disappear. Left side becomes water. Cloud remains. Water, mountain, and clouds are dark. Rest is sky and is light. Arrows still there.	

SCENE NO.	FRAME NO.	VISUAL	EXPLANATION	AUDITORY
27.25	416-450		Scene remains static. (Arrows, white lines disappear by 389).	
(28.0	451-617	Path of atomic tracer)	In this portion the lines are shown starting at the hill and going in the same process (to water, to sky, to cloud).	
28.01	451-459		Down mountain	Even the
28.02	460-469		Across mountain right to left.	path
28.03	470-482		Across water.	of a single
28.04	483-502		Up left side.	molecule
28.05	503-525		Over to cloud	of water can
28.06	526-564		Within cloud	be followed by atomic
28.07	565-571		Cloud to mountain	tracers.
28.08	572-617		Scene stays static.(580 - mountain range appears in background; center of screen extending to left).	
(29.0	618-637	Abstract factories)		
29.10	618-688	Abstract of buildings-static	Static.	Irrigation is expensive.
29.20	689-786	Growth of pipes	Pipes grow on above scene. They are all	

SCENE NO.	FRAME NO.	VISUAL	EXPLANATION	AUDITORY
			over, but start at the base of center and stay in a kind of diagonal area.	
29.21	787-837		Scene above (factories with pipes (29.2) remains static.	Often only industrial plants
30.01	838-877	Cross-section of purification plant	Above scene is fading while new one comes on--double image almost.	can afford the cost
30.02	878-908		New scene is clear and remains static. Building-plant at left, tree at right.	of raising water which can later be
30.03	909-950		Black water comes out of upper left pipe. Left to right. Water flows down filter bank.	purified
30.04	951-978		Water flows to right.	and reused for
30.05	979-1025		Scene now is static.	agriculture.
(31.0	1026-1154	Planning for irrigation)		
31.10	1026-1076	Blueprints	Static	This means accurate
31.20	1077-1154		Airplanes are superimposed on blueprints crossing the three large pipes, on a bit of a diagonal, about center of screen. Scene is static.	preplanning; miscalculations can mean

SCENE NO.	FRAME NO.	VISUAL	EXPLANATION	AUDITORY
(32.0	1155-1158	Irrigation)		
32.10	1155-1187	Water flowing through crops	Water flows through pipes left to right. Superimposed plans slowly fade. Crops become slowly visible in background.	damaging losses.
32.11	1188-1250		Plans gone. Water flows through pipes left to right. Crops in middle background. Pipes dark. Water light, background grey. No obvious single object.	Accumulation of salts can
32.20	1251-1358	Plants die	Plants wilt.	ruin crops.
33.10	1359-1507	Static (Umbrellas) Dynamic (Umbrellas)	Six grey umbrellas form middle of screen to bottom. This is not static. Rain is falling. New umbrellas pop up on top until they cover most of screen, continually disappearing and popping up. (Note: one by one.) Umbrellas are also moving from top to bottom but much slower than rain.	

SECTION X: Scenes 34.11 - 37.21; Frames 1 - 2108

SCENE NO.	FRAME NO.	VISUAL	EXPLANATION	AUDITORY
(34.01	1-30	Quick cuts: Uses of water)		
34.11	1-15	Man in shower	Man in shower upright at center of screen (top to bottom). Shower nozzle at top center spouts water which flows over man's head and shoulders. Background is dark.	Music

SCENE NO.	FRAME NO.	VISUAL	EXPLANATION	AUDITORY
34.12	16-38	Man in shower	Man leans right and then stays still, while other objects remain the same.	
34.13	39-57		Man leans to left and then stays static.	
34.20	58-76	Lady in shower	Woman with back to camera. Water flows from shower nozzle.	Plenty ...for all? We use so much more than we ever used before.
34.30	77-161	Plumbing	Plumbing with water flowing through pipes, no central object. Bathtub in center, various sinks, main pipe at bottom of screen.	
34.40	162-181	Automobiles	Cars lined diagonally. Front two lines (bottom of screen) quite visible. Double arrows move right to left along aisle.	
34.50	182-212	Washing machine	Static scene. Woman, washer and table left, background grey. Small black arrows moving from bottom to washing machine.	
34.60	213-245	Shampoo (zoom)	Static except zoom in to face. Background is tile. Woman shampooing hair. Has bath towel wrapped around her.	
34.70	246-268	Chef	Man faces camera with pan on his front left. Static crossed lines in back. (Tile)	
34.80	269-287	Man drinking water	Head and shoulders only, of man at center. Background is crossed lines. Man is leaning back, head turned left. Cup in hand on left side.	

SCENE NO.	FRAME NO.	VISUAL	EXPLANATION	AUDITORY
34.81	288-306	Man drinking water	Head and shoulders still of man at center, facing forward with head tilted back. Background is crossed lines. Cup on left side, in right hand.	
(35.0	307-545 Tap)			
35.10	307-340	Water from tap	Head on view of water tap. In center of screen. Background is dark (wall), water flows down from tap.	
35.20	341-545	Pan to glass	Camera moves down tap, down to glass in which the water is going and spilling over. <u>All</u> eyes should be in center of screen. Pictures begin to darken at 534 and gets darker to end at 545.	
(36.0	546-1651 Arousal sequence)			
36.10	546-617	Cut to 1,000,000	White numbers 1,000,000 across middle of screen. Most of back dark except for light lines. Arrows on those light lines disappear at 571; reappear at 594.	
36.11	618-642		Cut to 00; 600; 1,000, 000; 900, 000 Dark background, with two patches of white.	
36.12	643-665		Same numbers as 36.11 but new background. Some numbers barely visible. White patches cover some of the numbers.	

SCENE NO.	FRAME NO.	VISUAL	EXPLANATION	AUDITORY
36.13	666-685		Back to 36.11 background. Same numbers.	
36.14	686-713		Back to 36.12 background. Same numbers.	
36.15	714-801		New numbers. Dark background. Dotted lines at upper right in background, come on a little right to left. Dotted lines move right to left. (Dotted lines at upper right start to fade at 727. More lines at left at 736. More lines disappear right at 752. New lines left at 758.)	
36.16	802-825		All zeros. Smear across center of screen.	
36.17	826-847		Same as 36.16, except lower left changes. White objects become more white and prominent.	
36.18	848-868		Looks like a pile of rubbish burning, smoke rising from right bottom to left top.	
36.19	869-890		All zeros, rows of white zeros on background of 36.18.	
36.20	891-939		Cut to all zeros but more, since smaller. Plain black background.	
36.21	940-964		Same zeros but some at bottom middle turn dark and scattered ones turn grey or white.	
36.22	965-984		Same zeros but no dark ones any more. A few white or grey ones.	
36.23	985-1005		Same as 36.22 but shift.	

SCENE NO.	FRAME NO.	VISUAL	EXPLANATION	AUDITORY
36.24	1006-1031		Same as 36.22.	
36.25	1032-1055		Same as 36.21.	
36.26	1056-1076		Like 36.23 shift.	
36.27	1077-1097		Like 36.22 shift.	
36.28	1098-1120		Same as 36.21.	
36.29	1121-1130		Like 36.22.	
36.30	1131-1207	Zeros disappear by 1160. At 1197, small circles begin to "crack" and divide into smaller circles.	Zeros change to circles and camera zooms in.	
36.31	1208-1334	Small white dots appear all over at 1325.	Circles become smaller. Camera continues to zoom in.	
36.32	1335-1434		Circles shrink to become small dots. Camera continues to zoom in.	
36.33	1435-1510	Vertically moving field as people become rain	Slight cut. Same circles as 36.32. Camera stops zooming but moves circles upward.	
36.34	1511-1651		Circles become raindrops falling from top to bottom and diminish somewhat.	Will there be enough?

SCENE NO.	FRAME NO.	VISUAL	EXPLANATION	AUDITORY
(37.0	1652-2108	Drop of water)		
37.10	1652-1786	Single drop of water	Large drop, hanging down in center of screen begins to appear behind small drops. Small drops are gone by 1665. 1664-1780 (static shot of drop).	There is as much water now as
37.20	1787-1987	Drop grows and becomes earth	Drop grows. Loses top tail at 1814. Becomes earth at 1987.	there ever was; no more, no less. But today increasing pollution has
37.21	1988-2108		Static of earth, dark background, earth in center.	brought us to the verge of a world-wide water crisis.
			Calibration Target (283 frames) Blank screen (29)	

SECTION XI: Scenes 38.11 - 41.07; Frames 1 - 769

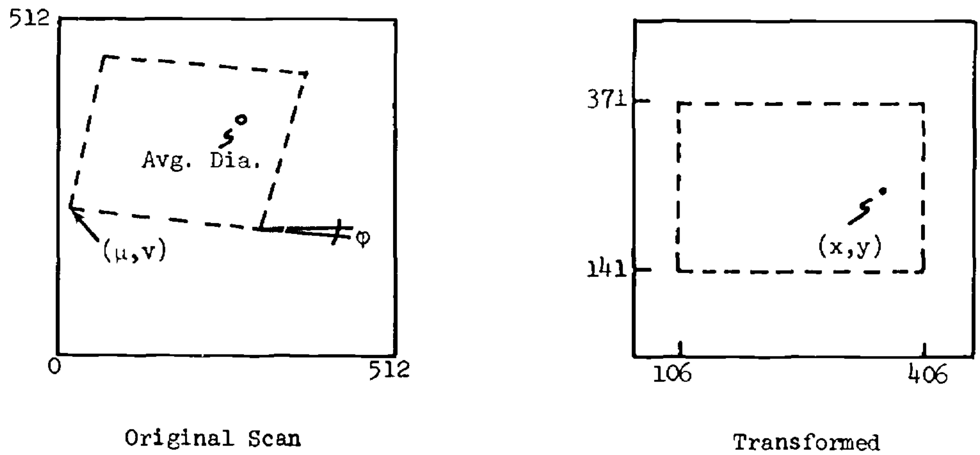
SCENE NO.	FRAME NO.	VISUAL	EXPLANATION	AUDITORY
(38.0	1-553	Photographs of people)		
38.1	1-71	Old man	Background is dark with a couple of white patches here and there. Shoulders and head are about in center of screen. Static scene. Beard stands out. Head piece also stands out.	The question in human terms

SCENE NO.	FRAME NO.	VISUAL	EXPLANATION	AUDITORY
38.12	72-112		Double image.	is this:
38.21	113-166	Woman and child	About same lighting. Static. Woman left, child at right, middle.	Where is the water when we need it?
38.22	167-204		Double image.	
38.31	205-224	Woman and child	About same lighting, different woman and child.	And in what condition
38.32	225-250	Double image.		is it when we get it?
39.01	251-270	Schematic; pan from river to water cycle.	Shot of river coming forward, white dotted lines moving forward (toward viewer-actually from top to bottom of screen) indicate flow of river. River extends across bottom of screen, but is narrow at top of scene. Vertical, dotted lines on left and right side of screen move from bottom to top of screen. Background is dark.	
39.02	271-406		Camera moves back from scene in a reverse zoom. As it does, dotted lines continue, but river becomes less dominant. Top of mountain appears in background at 285-319. Sky above it is seen (320-345). Then cloud above becomes visible (346-384). Next, sky above cloud is visible (385-395). Rain emits from lower part of cloud. Cloud, mountain, and "valley" are dark. Sky and river are light.	In the water cycle three-quarters of the earth is covered by oceans; the rest is in the air, on the

SCENE NO.	FRAME NO.	VISUAL	EXPLANATION	AUDITORY
39.03	407-553		Dotted lines continue to move, but camera (and thereby major objects) does not. i.e., lines and rain from cloud dynamic, while the rest is static.	earth or beneath the earth.
40.01	554-673	Airplane	Airplane remains stationary but ground below moves from top to bottom. Nothing particularly significant about the ground except that it is moving. Airplane dark, ground is lighter, plane at bottom of screen. Only front of airplane shows, viewer looking down on both airplane and ground.	Imagine this water as it passes from nation to nation, the demand
41.01	674-685	Flags; background moves horizontally.	Only background moving left to right. (Background moves from 674-769.)	constantly *increasing.*
41.02	686-697		Flag appears on right side of screen.	
41.03	698-709		Flag appears on left side (grey). Right flag remains (grey).	
41.04	710-721		Right flag becomes black, with object on it. Left flag remains.	
41.05	722-733		Left flag changes (same position). Grey and white fish on it.) Right flag (black) remains.	
4106	734-745		Large flag (black with white wheat) appears in center of screen superimposed on other flags, cutting off the right side of left flag and the left side of the right flag.	
41.07	746-769		Large flag covers the last center one and more of the other two. It is black with a light bulb.	

APPENDIX H

TAPE AND DATA FORMATS



BLOCK LABEL FORMAT

Film Serial N°	Film Section N°	Film Section Record N°	Missing Data Frame Count	Total Frame Count
0 5	6 11	12 17	18 26	27 35

BLOCK 1 DATA FORMAT (Transformed Units)

X_i	Y_i	X_{i+1}	Y_{i+1}
0 8	9 17	18 26	27 35

BLOCK 2 DATA FORMAT

μ	v	Error Code	Avg. Dia. Eyemarker	Tan φ
0 8	9 17	18 20	21 26	27 35

256 Film frames/record, 2 fixed length blocks per record, unused portions of last block pair for each film section filled with zeroes. Data in Block 1 packed 2 film frames/word. Data in Block 2 packed 1 film frame/word. All data binary integer except tan φ, given in 1's complement with G bit fraction.

PRIMARY DATA TAPE FORMAT

BLOCK LABEL FORMAT ~ 2 words

Subject Sequence N°	Film Section N°	Initial Frame N°	Final Frame N°
0 – 5	6 – 11	12 – 23	24 – 35

Next Subject Sequence N°	Next Film Section N°	Next Initial Frame N°	Next Final Frame N°

BLOCK DATA FORMAT ~ 256 words

	Index N°	VMAG	VPHI	Tag = 2	▨	y'	x'
0	1 – 3	4 – 11	12 – 17	18 – 20		26 – 30	31 – 35

Data packed 1 frame/word, 256 frames per block with the unused portion of each block of a section filled out with zeroes. Data sequential by ascending section N°s and by subject sequence N°s within sections.

VMAG units 3' arc. VMAG $\geq 377_8$ (12°45') given as 377_8.

VPHI units 6°. $0 \leq$ VPHI ≤ 60 with VPHI = 0 indicating undefined direction (VMAG = 0).

$Bit_0 = 0$ indicates VMAG and VPHI data present,
$Bit_0 = 1$ Missing. Missing VMAG and VPHI data given as zero.

x'y' units $\frac{1}{2}$° arc. with IR2 used as base register, address bits of packed data word point to entries in 24x32 array, which corresponds to original stimulus field (x'o to 30, y'o to 23) with an extra unused column vector (x' = 31).

$x' = 0, \; y' = 0$ (00000_8) Indicates missing data.

$x' = 30, \; y' = 0$ (00036_8) Indicates position external to field.

$x' = 0, \; y' = 23$ (01340_8) Indicates position of corners.

VMAG DEFINITION

$$VMAG_i = [(X_{i+1} - X_i)^2 + (Y_{i+1} - Y_i)^2]^{1/2}$$

Result computed as rounded integer

VPHI DEFINITION

$$VPHI_i = TAN^{-1} [(Y_{i+1} - Y_i)/(X_{i+1} - X_i)]$$

Result computed as rounded integer

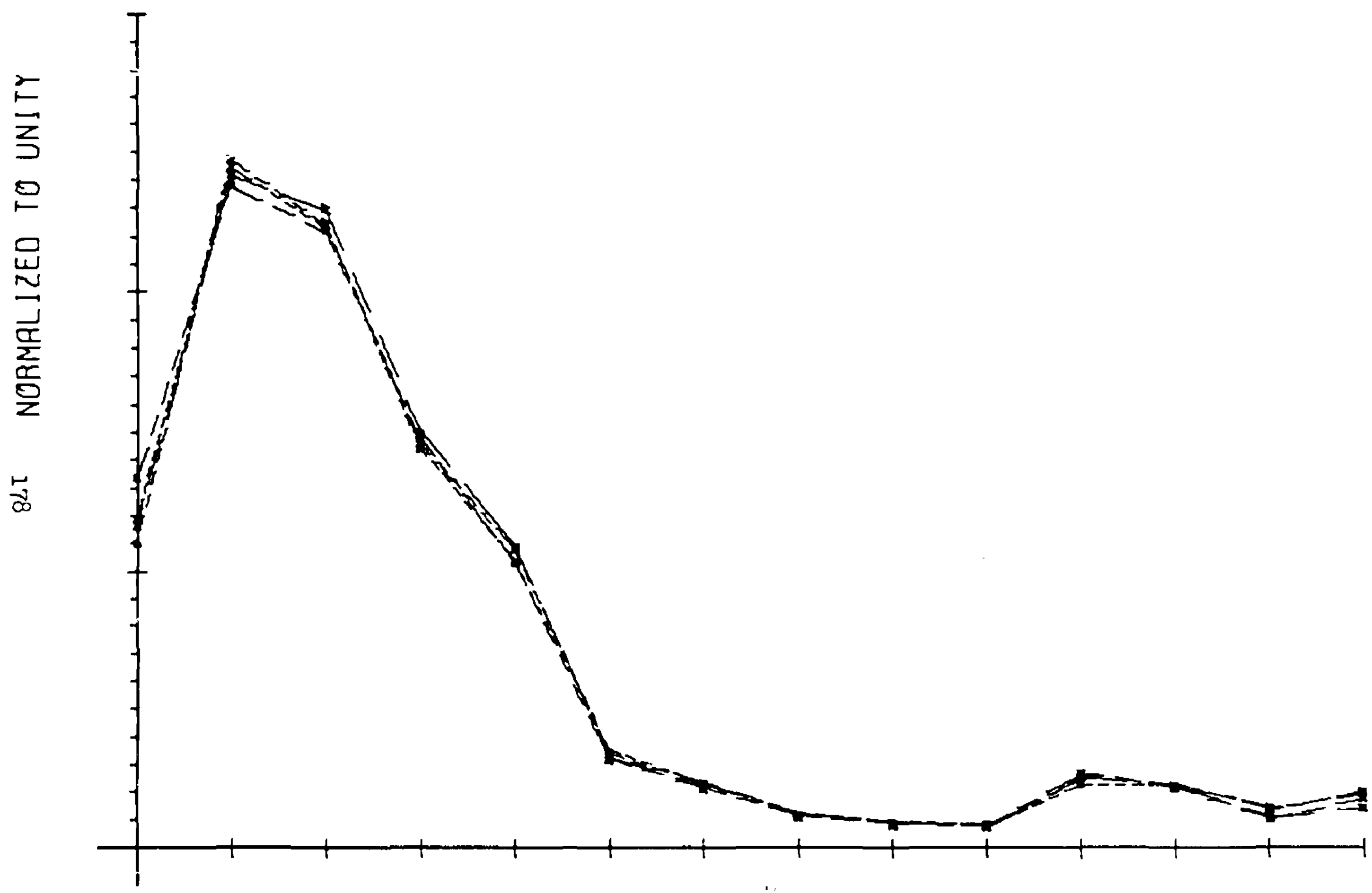
APPENDIX I

DENSITY CLUSTERS HIGH AGE SUBJ 2.3 BEFORE RAYS

```
        L
                                            J
    K   .   .       .                       J
        K   .   .   .                       .   J   J   J
            .   .   C   .   .   .   .   .   .   J   J
    M       .   .   C   C   .   .   .   A   .   .   .       B   .   I   .
    .           C   .   .   .   A   .   A   A   .   .   B   .   .   .
        D       .   .   .   .   .   A   A   A       .   B   .   G
        D       .   D   .   A   .   A   A   A   A   .   B   .   .
            D   D   .   .   A   A   A   A   A   .       B   B
        D   D   C   .   .   .   A   A   A   A   A
N       C       .                       A   .   .       H   H   H
                                E   .       .   F       H   H
                                E       F   F   F
                                            F   F
```

DENSITY PLOT HIGH AGE SUBJ SC 2.3 BEFORE RAYS

		3																
											3							
	3	1	2		1						4							
		3	2	1	1						3	11	2	2				
			1	2	10	1	3	9	12	9	6	12	7					
	2		1	4	29	29	12	12	4	18	8	2	6		19	1	13	1
	1			15	12	19	28	29	11	14	21	5	1	40	8	1	5	
		3		1	3	7	2	25	35	45	8		3	22	10	16		
		4		1	21	15	27	7	57	55	4	10	4	16	2	1		
			6	28	1	19	26	54	83	27	12	2		9	15			
		6	9	8	6	2	3	74	53	28	13	12						
1		3		3						18	7	2		1	6	13		
								18	1		1	18		2	1			
								9		11	12	16						
											4	2						



MEAN VMAG DISTRIBUTION BY FILMS (26 SUBJECTS)

C18001 10/03/68 1.00

APPENDIX J

OVERALL DESIGN
THREE FACTOR - REPEATED MEASURE

			FILMS			
			1	2	3	4
High Age	High IQ	S_1				
		S_2				
		S_3				
	Medium IQ	S_4				
		S_5				
		S_6				
	Low IQ	S_7				
		S_8				
		S_9				
Medium Age	High IQ	S_{10}				
		S_{11}				
		S_{12}				
	Medium IQ	S_{13}				
		S_{14}				
		S_{15}				
	Low IQ	S_{16}				
		S_{17}				
		S_{18}				
Low Age	High IQ	S_{19}				
		S_{20}				
		S_{21}				
	Medium IQ	S_{22}				
		S_{23}				
		S_{24}				
	Low IQ	S_{25}				
		S_{26}				
		S_{27}				

FILMS

SUMMARY TABLE

Source of Variation	df	F
Between Ss		
IQ	2	$MS_{IQ}/MS_{Ss/IQ,\ Age}$
Age	2	$MS_{Age}/MS_{Ss/IQ,\ Age}$
IQ x Age	4	$MS_{IQ \times Age}/MS_{Ss/IQ,\ Age}$
Ss/IQ, Age	18	
Total	26	
Within Ss		
Films	3	$MS_{Films}/MS_{Films \times Ss/IQ,\ Age}$
Films x IQ	6	$MS_{Films \times IQ}/MS_{Films \times Ss/IQ,\ Age}$
Films x Age	6	$MS_{Films \times Age}/MS_{Films \times Ss/IQ,\ Age}$
Films x IQ x Age	12	$MS_{Films \times IQ \times Age}/MS_{Films \times Ss/IQ,\ Age}$
Films x Ss/IQ, Age	54	
Total	81	
TOTAL	107	