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A STUDY OF PHOTOINTERPRETER PERFORMANCE IN CHANGE DISCRIMINATION

C. L. Klingberg
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The Boeing Company
Seattle, Washington

D2-90550

AF 30(602)-2698

Project Number 6244
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Prepared
for
Rome Air Development Center
Air Research and Development Command
United States Air Force

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FOREWORD

This report was prepared by Carl L. Klingberg, Conrad L. Kraft, and Charles L. Elworth of Engineering Psychology, Bioastronautics, Central Technical Staff, Aero-Space Division of The Boeing Company, Seattle, Washington. It covers research performed under Air Force Contract No. AF 30(602)-2698, Project No. 6244, Task No. 624402. The work was sponsored by the Information Processing Laboratory, Rome Air Development Center, Griffiss Air Force Base, New York, with Mr. J. Alfred Stringham as Project Engineer. The Contract Monitor was Dr. Shelton MacLeod of the Human Engineering Laboratory, Rome Air Development Center, Griffiss Air Force Base.

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The assistance of the following members of our research staff is gratefully acknowledged: Dr. Lowell M. Schipper for his contributions to statistical design and review; Mr. Harold H. Davis for the data collection, reduction, and computation; and Mr. Michael C. Carr for his organization and categorization of the aerial photographs and preparation of stimulus material.

ABSTRACT

Two methods of inspecting pairs of comparison photographs were studied: 1) side-by-side display; and 2) apparent-motion display, in which pictures in spatial registry were presented in temporal alternation. This second presentation method produces apparent motion, where a difference between the pictures exists, which aids in the rapid detection of objects that have changed.

Both experienced and inexperienced interpreters were tested with aerial photography varying in scale, contrast, resolution, and terrain complexity.

Under certain conditions the apparent-motion display method was found to enhance significantly interpreter performance in the change detection task. However, it became relatively less effective with poorer quality imagery or where these was a high percentage of irrelevant change. Under difficult conditions, neither display method was significantly better than the other.

Although the applications of the apparent-motion technique are limited, the results of this study suggest the value of further efforts to define the extent of its usefulness.

PUBLICATION REVIEW

This report has been reviewed and is approved. For further technical information on this project, contact Mr. Alfred J. Stringham, RAWIC, Ext. 4104.

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INTRODUCTION

THE PROBLEM: INCREASING DEMAND FOR RECONNAISSANCE

Since the development of military aircraft, each major conflict among nations has produced heavy demands for aerial-reconnaissance information. The Russian buildup of missiles in Cuba propelled aerial reconnaissance into the limelight as one of the nation's first lines of information.

According to John McCone, Chief of the Central Intelligence Agency:

> "Every war of this century, including World War I, has started because of inadequate intelligence and incorrect intelligence estimates and evaluations. This was true of Pearl Harbor, for example, and it was true in Korea. The Cuban crisis in October could have generated a war, some think a nuclear war. But war over Cuba was avoided because of intelligence success. Every threat to our security, every weapons system, was correctly identified in time to give the President and his policy advisers time to think, to make a rational estimate of the situation, and to devise a means of dealing with it with a maximum chance of success and a minimum risk of global war. I consider this an intelligence success. Although intelligence is not a measurable commodity, that is at least a partial measure of its value." (Alsop, 1963)

THE BOTTLENECK: INFORMATION EXTRACTION

Historically, the reconnaissance system has always been an ancillary system; weapon systems have received the higher priorities in design and development of equipment, manufacture, and manpower. In addition to this secondary role, there has been a developmental imbalance within the reconnaissance system. The development of airborne and space-observation platforms, reconnaissance sensors, and methods and equipment for storage and retrieval has moved ahead with rapid technological strides. In contrast, almost completely neglected were the scientific investigations of three man-machine interface areas associated with information extraction: (1) classifying the usefulness of the pictures, (2) encoding pictures for easy retrieval, and (3) interpreting (i.e., transforming pictures into linguistic, digital, or analog forms of information and relating these new data to previous information).

The flow of information through the reconnaissance system is no faster than its least efficient subsystem. The amount of intelligence data that can pass through our limited capabilities of classifying, encoding, and interpreting pictures cannot be increased by greater expenditure of money and time on the already advanced technologies of platforms, sensors, and storage devices.

Photointerpreters must work in all three areas of classifying, encoding, and interpreting pictures. Since their skills are most needed in the interpretation of aerial photography and in the transformation of images into meaningful terms, efficiency would demand that the photographs placed before them would be preselected for good quality, coded for information content and image characteristics, identified by geographic location, and indexed by areas that have a high probability of containing information.

The requirement for global surveillance, wherein pictures from space and from the atmosphere would be used to keep all nations well informed as to the activities of each, greatly increases the problem of information extraction. On the basis of of the photographic output of the earliest weather satellite and the published information about our military needs, we could collect enough pictures to keep approximately 50,000 photointerpreters busy. (Kraft and Hamilton, 1961; Kraft and Klingberg, 1962.) The number of trained and active photointerpreters is far less than 50,000. However, current operational practice operates on the philosophy that the photographic interpreter is the "one who knows what he is looking for," a philosophy that requires his participation in all data-transformation phases.

The limited number of trained photointerpreters and their widespread use within the system combine to make the man-machine interfaces the critical problem areas of the reconnaissance system.

APPROACHES TO SOLVING THE PROBLEM

The most frequently suggested solution is to build automatic machines to do the classification, encoding, and interpretation jobs. However, complete automation is not the immediate answer. If and when completely automatic equipment is design and built, its complexity and its associated maintenance cost will have to be compared with its effectiveness.

A second solution is to increase the number of trained photointerpreters. To maintain a staff of 50,000 or more trained photointerpreters would require an entirely new selection and training program, and a special military or civil-service job category. The latter would be necessary to provide economic and community status inducements to maintain long-term job satisfaction so that the individual's training and experience would remain available to the using agencies.

A third alternate appears to be the most promising and immediately applicable. This alternate is the scientific study of man and machine performance within the reconnaissance system and the application of these evaluations to improve the performance of the semiautomatic system. The goal would be the optimum design of equipment, use of procedures, assignment of tasks, and organization of work environment against a criterion of maximum man and machine performance in processing of reconnaissance information.

The overall problem is too large to be handled at one time by any single organization, but a beginning is to determine if the design or redesign of display equipment would permit large numbers of briefly trained persons to take over part of the interpreter's task. This would be feasible only if it could be demonstrated that the briefly trained individual could, with a special display, perform as efficiently as a fully trained interpreter. System performance could then be improved by having the experienced photointerpreter apply himself more to technical interpreting — the task most demanding of his training and experience.

One of the important tasks of the photointerpreter is to detect meaningful changes in comparative-cover photography. Comparative-cover photography consists of two or more images of the same terrain obtained at different times. Comparison of the two photographic samples then provides difference information on changes that might have occurred in the elapsed time. The differences or changes, if relevant to man's activity, are then the sources of information that provide intelligence about his activities. World War II provided examples that amplified the importance of this comparative technique. One such example is the photograph of the northern Axis ports obtained by a British Spitfire 3 days before the Norway invasion. Because of the absence of a comparative standard, the ports' invasion preparations were interpreted as "normal port activity." On the other hand, an excellent example of the usefulness of the technique occurred when the Allied powers were able to observe the progress of the V-1 buildup through the comparison of successive photographs. By bombing the sites just before their proposed initial use, they significantly delayed use of the V-1 as an operational weapon.

METHODS OF DISPLAYING COMPARATIVE-COVER PHOTOGRAPHS

The availability of two photographs of the same terrain makes possible direct comparison. Experimental evidence shows man to be far more effective in making comparative discriminations than in making absolute (no physical standard) discriminations. The efficiency of methods of displaying comparative-cover photographs might therefore vary as a function of the degree to which they provide ideal conditions for comparative judgments.

The visual-perceptual elements of the change-discrimination task (rather than the cognitive elements of the task) appear to be primary, and display designs optimizing the conditions for visual discrimination might: (1) improve the performance of both trained and untrained observers, and (2) for this task, permit the performance of the non-photointerpreter to be comparable to that of the trained interpreter. If research findings established the validity of the latter or both suppositions, a division of tasks would improve the efficiency of the system. The tasks that are more dependent on the visual-perceptual elements could be assigned to quickly trained personnel using specially designed equipment, and the tasks that include principally cognitive elements would be reserved for the photointerpreter.

The initial step in the study of using man-machine optimization was to ascertain what visual information should be attenuated, what information should be enhanced, and which display methods would be operationally feasible. Changes in number, size, position, color, and configuration must be enhanced by the display system. Identical areas in both photographs should be attenuated by the display system. Another dimension of the problem is that changes can be either relevant or irrelevant. Relevant changes are those that tell of man's activity or of conditions of nature that would affect his activity. Natural changes that do not significantly alter man's activity are considered irrelevant to the requirements of the intelligence organizations. The enhancement of all changes, relevant and irrelevant, might not increase the flow of information: large numbers of enhanced irrelevant changes might even reduce it. For example, a large difference in sun angle between the two pictures will result in an increase in the amount of irrelevant change as a function of the number of tall objects in the scene. Therefore, the display, in addition to enhancing the changes and attenuating the nonchanged area, must permit differentiation into relevant and irrelevant changes. Accordingly, the ideal display of reconnaissance photography should result in the transmittal of information to intelligence as it is represented in Table I.

Table I INFORMATION TRANSMITTAL FROM AN IDEAL CHANGE-DETECTION DISPLAY

		CHANGES IN THE PHOTOGRAPH	
		NONE	SOME
RELEVANCE TO INTELLIGENCE ORGANIZATIONS	RELEVANT	No Change Recognition and No Report A	Detection, Recognition, and Report B
	IRRELEVANT	No Change Recognition and No Report C	Detection, Recognition, and No Report D

The ideal display should maximize the conditions leading to reports of change associated with the Box B in Table I. Errors of omission are a product of a nonreport from Box B, and such errors would decrease the measure of completeness. The ideal display should facilitate the recognition of no change in Boxes A and C, a condition that would be reflected in lower time scores. Reports of changes from Box D are errors of commission that reflect inability to determine the relevance of the change. Reports of changes from Boxes A and C would reflect errors of commission based on an inability to discriminate unchanged areas from changed areas.

SIDE-BY-SIDE METHOD

The comparison of two photographs, without specialized equipment, is made by placing the two prints side by side and looking from one to the other in making the visual analysis. The simplicity and directness of this method had made it the operational standard, especially in the field. The interpreter's aids for this method are magnifiers, light tables, measuring devices, and interpreter keys. Essentially, the method of side-by-side comparison is unchanged by the addition of these aids. This method was chosen as the basis for comparison with other display methods.

OVERLAY METHOD

One experimental approach involves the attenuation of the brightnesses of all unchanged areas. This might be accomplished by sandwiching negative and positive photographic transparencies in registry in a single optical light path. Changes should appear lighter or darker against the gray of equal attenuation by the negative-positive subtraction.

Perfect registry of the two sets of images prevents the observer from recognizing the shapes of objects and therefore interferes with the discrimination of relevancy of the change. Slight misregistry will produce outline figures, as in Figure 1, when the stimuli are simple forms, and a bas-relief effect with more complex stimuli as shown in Figure 1B. This permits some degree of form recognition and discrimination of relevance.

A variation of the overlay method is to place the negative transparency in one optical pathway and the positive in a second pathway, combining them with a two-way mirror so the observer sees them in slight offset registry. The two pictures combined in this way produce a "silvery" appearance for simple forms. This appearance has been called Titchener's "scintillation effect." His early handbook on experimental laboratory methods included five stereoscopic slides that produced this phenomenon (Titchener, 1901 and 1915). The effect is produced by stereograms with a black-line figure on a white field (square, rectangle, or three-dimensional drawing) presented to one eye and a white-line drawing (also on a white field) presented to the other eye but with the internal area of the figure black in color. This internal area common to the two figures will be seen as "silvery" when second-degree fusion occurs for the observer viewing the card in a stereoscope.

In the studies reported here, the overlay method used two optical beams with a slight offset in the alignment of positive and negative transparencies.

APPARENT-MOTION METHOD

The apparent-motion method, as used in these investigations, consisted of placing a positive transparency in one optical pathway, the comparative positive transparency in the second pathway, and combining them with a two-way mirror so that the observer saw them in registry. The two pathways were illuminated alternately in as near an approximation to a square wave pattern as the mechanical shutter permitted. Two identical and registered pictures, combined in this way, produce the appearance of a single continuous picture. Nonidentical areas of the two transparencies appear to move since the alternation rate of 1.5 cycles per second is within the range in which apparent motion is perceived.

The use of this phenomenon in developing a display that would enhance change detection is based on two assumptions:

1) The detection threshold for a moving (changing) object would be lower than that for stationary objects. As early as 1878, G. H. Schneider (Boring, 1942) had determined that a moving shadow is more perceptible than a still shadow.

2) In most instances, the number of moving objects would be a smaller portion of the number of objects in the field of view. Thus, the changed object would contrast with the surrounding stationary objects.

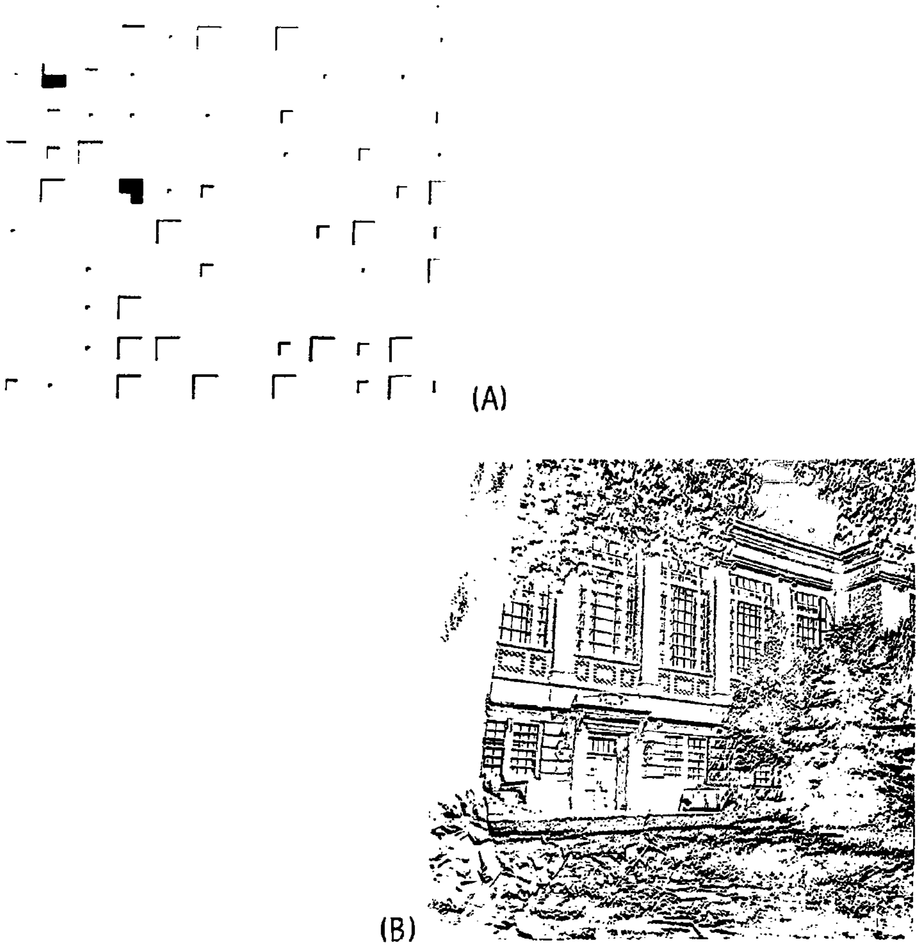


Figure 1

BAS-RELIEF EFFECT IN STIMULI OF LOW COMPLEXITY (A), AND HIGH COMPLEXITY AND LARGE DISPLAY SCALE (B).

The history of apparent motion, as distinguished from the perception of real motion, began in 1820 with Purkinje's phenomenological description of seen and felt motion in giddiness (Boring, 1942). Apparent motion, free of nystagmic eye movements, was described by Roget in 1825 on noting the stationary appearance of a moving carriage wheel when viewed through a picket fence. In the following 10 years, Plateau and Stampfer independently developed the concept and the device known as the stroboscope. The earliest thorough discussion of the phenomenon is to be found in Helmholtz's Handbuch der Physiologischen Optik (1860), and Thomas A. Edison in 1894 made a practical use of the phenomenon in the development of motion pictures. Although Edison's kinetoscope started a series of applications such as the "moving" billboards, railroad-crossing signals, and Times Square "newspaper in the sky," it was Wertheimer (1912) who simplified the observational situation, presenting a single discrete displacement of a form with a tachistoscope. As he varied the time interval between the presentations of these two forms between 0.030 and 0.200 second, he observed a series of different kinds of apparent movement. In order of increasing time intervals, he reported simultaneity, optimum movement, partial movement, pure movement, and succession. Wertheimer's explanation of what occurred, with the right time intervals to produce pure movement, was that the seen movement was like a "physiological short-circuit" in the brain — a cortical process that is the physiological substrate of apparent motion. Wertheimer's paper, with the then-current enthusiasm for Gestalt psychology, produced such interest that more than a hundred papers on apparent movement appeared in the next 30 years. Among these were three that isolated and named six types of apparent motion besides that which Wertheimer called phi movement. These types of motion all would be seen in discriminating changes in photographs. These types of changes are listed here by the names the authors gave them but defined in terms of their application to comparing aerial photographs for change.

Beta movement (Kenkel, 1913): An example would be that of two photographs taken 1 minute apart of an army tank in motion. The two pictures would show the tank in two different locations along the line of its track. When viewed in the apparent-motion equipment, the tank would appear to be jumping back and forth between the two photographed positions.

Alpha movement (Kenkel, 1913): If a long building had been extended in the time between the two comparative coverages, in the apparent-motion device the observer would see the building alternately lengthen and shorten.

Gamma movement (Kenkel, 1913): If an oil tank in a tank farm had been replaced by a larger tank, its appearance would be as for alpha movement, a change in size; but the gamma motion is like a swelling and shrinking, or a motion along the line of sight toward the observer. Gamma movement may also be seen where there is a brightness difference in an ambiguously defined area such as specular reflection on water.

Delta movement (Korte, 1915): A reversed movement from the order of presentation due to the relative brightness. A motion that might be perceived but not differentiated from gamma in this display due to the presentation order of the photos not being known to the observer.

Bow movement (Benussi, 1916): A curved movement that does not follow the shortest distance between two points. An example would be a portable airplane-repair platform that had been moved to the other side of the fuselage between photos. This would appear to move with a curved course over the airplane.

Split movement (De Silva, 1926): Such motion may be ambiguous, such as a single packing case seen in one photograph, but between two other crates in the second photograph. The apparent motion appears to originate with the single crate and go two directions toward the two new crates.

Another visual phenomenon, although not true apparent motion, is important in discriminating changes in photographs. If an object is removed or added, and no similarly shaped or sized object is nearby, the added object produces a flicker.

Although all these classifications of apparent motion are seen by people in the course of using the apparent-motion display apparatus, knowledge about types and extent of motion is not essential to the discrimination of change. The types of motion, on the other hand, could be developed as aids in determining what change has occurred and its relevancy.

EARLY RESEARCH IN THIS LABORATORY

The three display techniques reviewed above — side-by-side, overlay, and apparent motion — have been used in a series of experiments on change detection in comparative-cover photographs.

Before these systematic experiments, a modified Wheatstone stereoscope was used to investigate change detection with the apparent-motion technique (Larry, 1960). With this equipment, it was possible to vary the rate of alternation, provide a steady illuminance to one beam and pulse the other, or have two steady illuminances. With the stereoscopic display, one eye sees the earlier photographic sample and the other eye is presented with the new sample. However, the steroscopic approach was not used in the series of studies that follow for these technical reasons:

1) Stereoscopic viewing makes second-degree fusion almost impossible for subjects with any degree of convergence-accommodation imbalance when the objects viewed are a negative to one eye and a positive to the other eye.

2) The apparatus is not easily adapted to all three display conditions — side-by-side, overlay, and apparent movement.

3) The interobserver variability would be excessive unless subjects were selected on the basis of ideal visual skills.

A second instrument was designed that would not have these limitations. Figure 2 is a functional diagram of the apparatus. The illuminance for the two optical pathways for the photographic slides emanates from a single source. The tungsten lamp was housed in an air-cooled aluminum sphere drilled to provide two point sources, one for each optical path. A variable-speed motor powered the conical shutter that occluded the beams alternately. The shutter could be set in a fixed position and a second port opened permitting the simultaneous passage of both beams. The light emanating from the ports in the sphere was spread by the biconcave lenses to provide a large illuminated area on the opal screens. These illuminated opal screens were needed as area sources because the focusing of the point sources by the Fresnel lens resulted in an interference spectrum at the eyepiece. The thin plastic Fresnel lenses (14-inch focal length, 14-inch diameter) were mounted in 16-inch by 16-inch heavy aluminum clamping frames. The large-diameter Fresnel lenses allowed the side-by-side presentation of two 4-inch by 4-inch photographic transparencies within an equal-brightness homogeneous field. The slide holders were built so that the transparencies could be positioned in the center for apparent-motion and overlay viewing, or to one side for side-by-side viewing. The slide holders were not adjustable for individual slide-registration adjustments; slides are registered when mounted. The two-way mirror, mounted 45 degrees to the observer's line of sight, permitted simultaneous or alternate viewing of both pathways. The slides were centered when in registry.

The third optical path for the coding matrix was also registered with the centered slides. In side-by-side presentations, the coding matrix was positioned to register with the left side. The coding matrix has two illumination sources that operate independently. The observer activates the system by keying a lattice matrix of 36 squares ordered in six rows and six columns. This matrix is formed by painting an electro-luminescent panel to black out all areas but the lines forming the matrix. Centered within each square of this matrix is a 5/8-inch hole punched through the electroluminescent material. The electroluminescent panel is mounted as the front face of a small cabinet containing thirty-six 0.5-inch-diameter frosted panel lamps. The lamps are centered behind the cut-out areas in the electroluminescent panel. The individual lamps are illuminated as the observer presses the keys of a 36-unit push-button response panel that is external to the apparatus. These lights provide feedback information to the observer concerning his response to indicate the position of the change he detected in the photographic stimulus. The feedback is immediate upon pressing of the response key, but if he is in error, the circuitry permits him to release the key within 0.5 second without any recording of that response.

At the eyepiece, the arrangement of optics is designed to produce a luminous cone of light 3.5 inches in diameter, homogeneous in distribution of intensity and color. The viewing distance, or the eye-to-slide distance, is 21.5 inches.

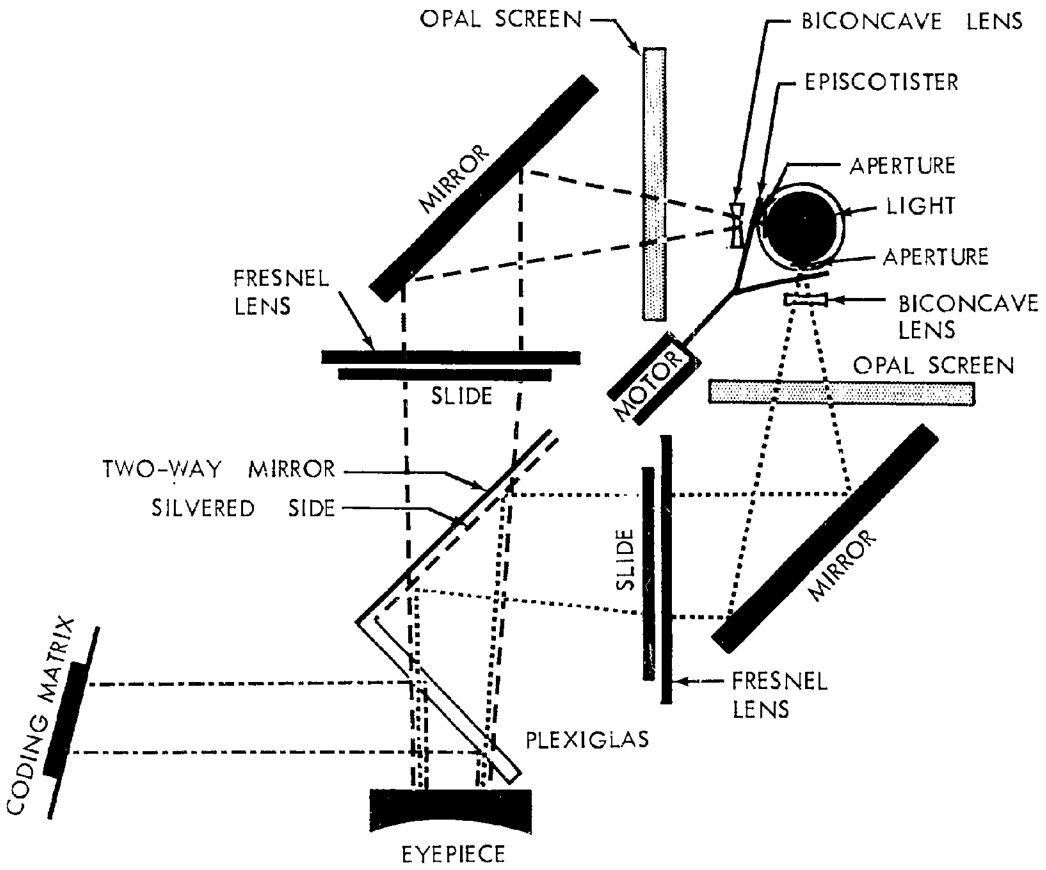


Figure 2 FUNCTIONAL DIAGRAM CHANGE DETECTION APPARATUS

Therefore, a 0.0062-inch object in the photograph subtends a visual angle of 1.0 minute. At a photograph-to-ground scale ratio of 1:14,500 as used in Experiments B, C, and D described below, an automobile 15 feet long would subtend 2 minutes of visual angle.

The illuminance level used in the initial study was 3.5 foot-candles as measured by a MacBeth illuminometer at the eyepiece. This represents the illuminance of the individual optical paths without any slides in the holders. While this illuminance level was adequate for the simple geometric stimuli of the first study, it had to be increased later for aerial photographic slides with their greater overall density. For all subsequent experiments, the single light source was replaced by two General Electric DEF projection lamps of 21 volts and 150 watts. This lamp has an internal parabolic reflector with a focal point at about 1.5 inches in front of the lamp. These lamps were positioned so that the conical shutter passed through the point of convergence of the rays, and the biconcave lenses were removed from the system because the diverging rays beyond the shutter provided a sufficiently large illuminated area on the opal screens. The illuminance level was raised to 10 foot-candles through this modification.

The response-panel equipment consisted of 36 push buttons arranged in six columns and six rows. An elevated divider separated this matrix into four quadrants of nine push buttons each. The divider was just higher than the key height and served as a tactual reference for the observer's hand position on the response panel. Most observers, as they became familiar with the equipment and task, used this tactual reference in combination with the visual feedback provided by the coding matrix. Connected with this response panel was a digital-to-analog converter that provided the input to a Hewlett-Packard digital recorder Model 560-A printer. The readout was digital in form. This record provided elapsed time from the start of a trial to each detection of a change as indicated by the activation of a response key. Associated with each of the 36 response keys was a digital representation of the location of the response. On the side of the response unit was a thirty-seventh key, which signaled that the oberver had completed his investigation; with its activation, the printer recorded a summation of elapsed time. In summary, the recording equipment provided these dependent measures:

1) Time in seconds from the beginning of a trial to each detection of a change;
2) Total time the observer used in the trial;
3) The location of the identified change as one of 36 possible outlined areas within the 4-inch by 4-inch display.

The four experiments immediately following were preliminary to those discussed in later sections of this report as part of the contract work specified in the Foreword.

Experiment A

The first experiment investigated the efficiency of detecting changes in synthetic pictorial data as a function of presentation method, type of change, and target size. A 3 by 3 by 3 factorial design was used, as shown in Figure 3. The three presentation methods are shown on the abscissa; the ordinate represents three of the five possible ways of classifying types of change, according to number, size, and position — the variables for the investigation. The synthetic stimuli were high-contrast photographs of squares in a homogeneous background. On the Z axis, the sizes of these squares were: Size 1, 4 minutes of visual angle; Size 2, 16 minutes; and Size 3, 32 minutes. The matrix includes 27 individual cells.

Figure 4 further defines the individual makeup of one of these cells. Each pair of slides was presented twice, but rotated 180 degrees for the second exposure. Slides contained either zero, two, three, or six changes; this number was unknown to the subjects.

Fifteen observers, who were previously trained on each of the three methods of presentation, reported the detected changes by location, with response time recorded by a digital printer. An average of 8.5 seconds per slide was needed to report the average of three changes.

The dependent variables for these studies were: (1) average inspection per slide, and (2) the error scores, which were divided into two categories: unreported changes and false reports of change.

Experiments B and C

The second and third experiments used aerial photography with two levels of "visual noise." The stimulus material was derived from 36 photographs obtained from the Central Intelligence Agency. The "minimal visual noise" photographs were operationally identical photographs, taken from the Airplane Position A in Figure 5, with target changes systematically introduced by an artist in one copy. The "high visual noise" photographs were a comparison of Picture A incorporating the changes introduced by the artist with Picture B of the same area taken from Position B of Figure 5. The two sets of photographs were in fact obtained on the same pass within a brief interval. The "high visual noise" is a correlated noise in that it is a product of the two different views of all three-dimensional ground objects, resulting in a common effect throughout the photograph.

The changes introduced on the 2.4-power enlargements are listed in Appendix II. These changes are distributed among four classifications: thirty buildings, seven transportation vehicles, seven industrial storage areas, and nine natural landscape areas. The changes were located within the 6 by 6 sector matrix as shown in Figure 6. With reference to experimental design (Figure 7), it would

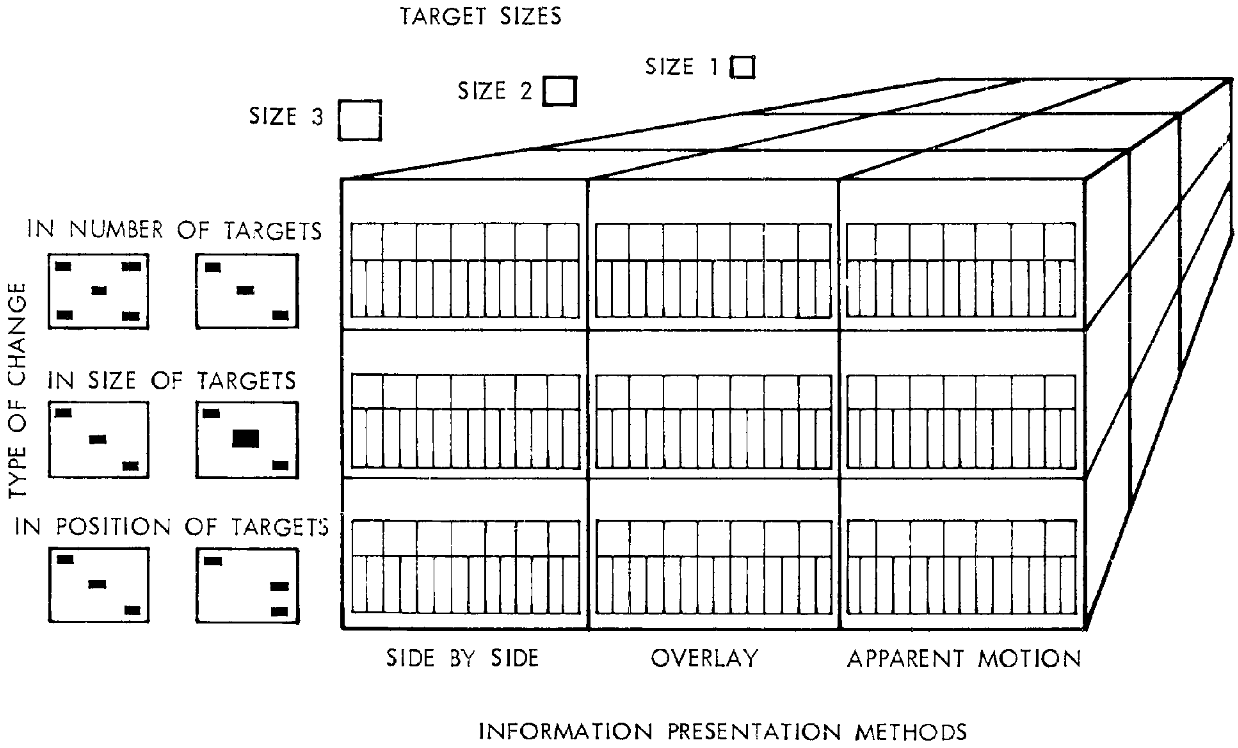


Figure 3 EXPERIMENT A: EXPERIMENTAL DESIGN
For Evaluation Of Methods Of Detecting Change

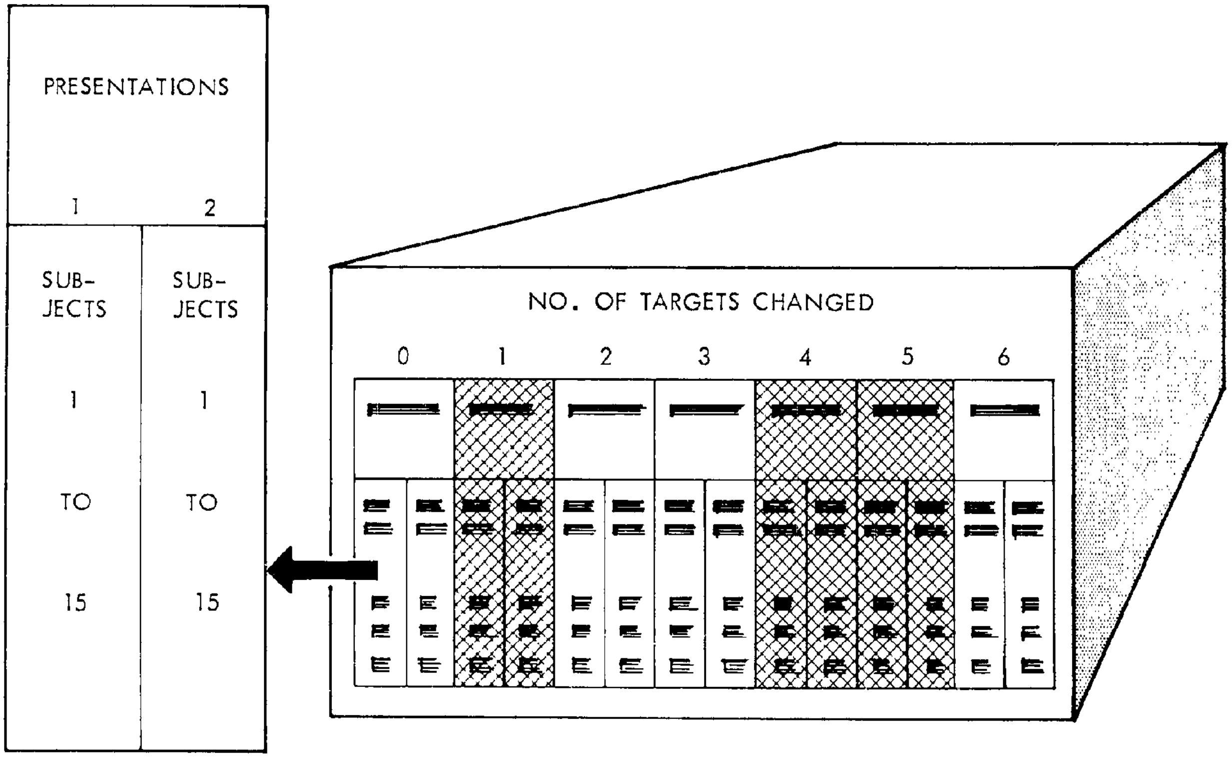


Figure 4 EXPERIMENT A: EXPERIMENTAL DESIGN
For Individual Cell

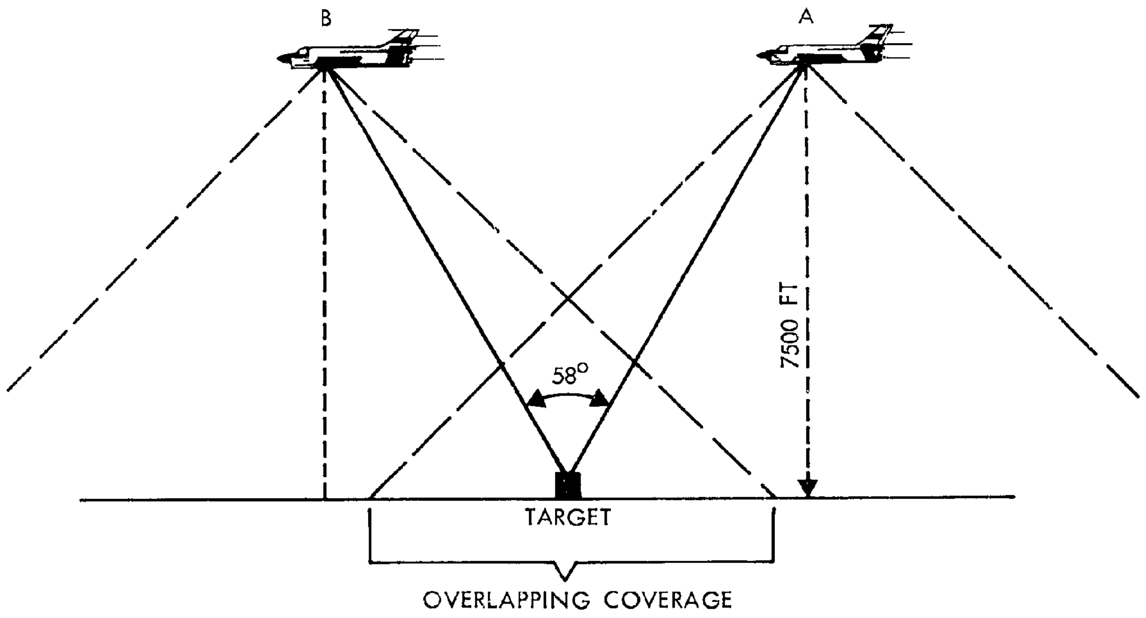


Figure 5 AERIAL PHOTOGRAPHIC CONDITIONS REPRESENTATIVE OF THE COMPARATIVE COVER PHOTOGRAPHS USED AS THE HIGH VISUAL NOISE STIMULI OF EXPERIMENTS C AND D (AND CONTRACT EXPERIMENT I)

	1	2	3	4	5	6	TOTALS
A	2 0	2 1	2 0	0 1	1 0	1 0	8
B	1 1	2 0	1 1	2 0	3 1	1 1	10
C	2 1	4 0	1 1	2 0	2 0	0 0	11
D	1 0	2 1	1 0	4 1	1 4	1 0	10
E	4 0	1 0	1 1	1 1	2 0	1 1	10
F	0 0	1 1	1 0	1 0	2 0	0 0	5
TOTALS	10	12	7	10	11	4	

0 TRAINING SLIDES

Figure 6 FREQUENCY OF TARGET CHANGE IN VARIOUS PARTS OF PICTURES

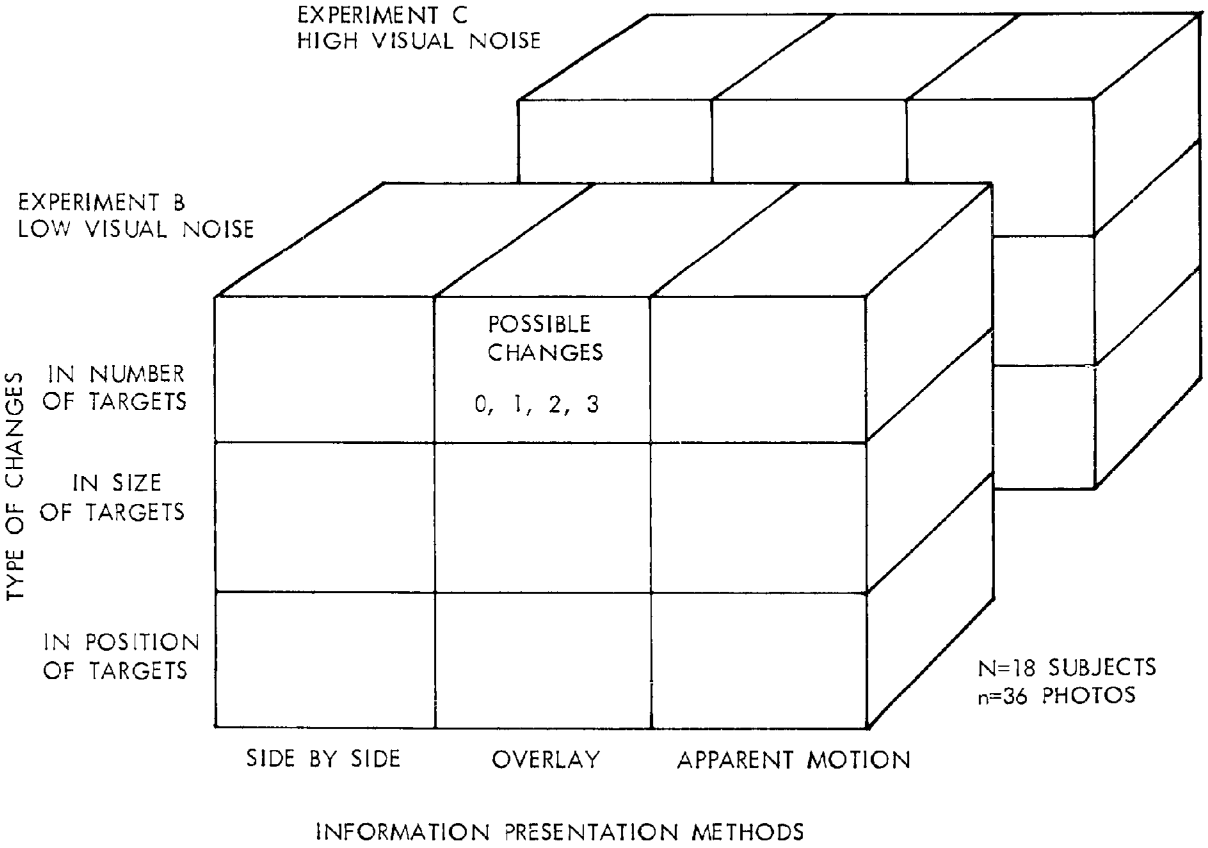


Figure 7 EXPERIMENTS B AND C: EXPERIMENTAL DESIGN AERIAL PHOTOGRAPHS

have been desirable to have changes occurring with equal frequency in all 36 sectors of the matrix. It also would have been desirable to have these sectors assigned at random throughout the set of test photographs. However, these conditions could not be met because of the need for the appearance of realism in the changes introduced in the photography.

In general, the original negatives were of high image quality and contrast. Fourth-generation reproductions of the original scale (1:14,496) were used in the comparator.

The average integrated transmission value for the 36 standard slides was 22.53 percent and the transmission varied among these slides to produce a standard deviation of 5.63 percent. The Position B members of the pairs, which were always compared with their standard counterparts, had a mean integrated transmission of 19.48 percent and a standard deviation of 5.12 percent. With the beam intensity set at 10.0 foot-candles, the average illuminance of the slides was 2.1 foot-candles, and the average brightness difference between the paired stimuli was 0.30 foot-candle.

The individual target transmissions and the average immediate surroundings were measured with a densitometer. The 54 targets were distributed about equally as to negative and positive contrast; 29 targets were darker than their surroundings. The percentage contrasts were distributed as shown in Table II.

Table II DISTRIBUTION OF 54 CHANGED TARGETS BY PERCENT CONTRAST

PERCENT CONTRAST	NUMBER OF TARGETS
0 - 9.9	2
10 - 29.9	17
30 - 59.9	18
60 - 89.9	11
90 - +	6

The results of Experiments A, B, and C indicate that an observer could detect changes faster and more accurately with the apparent-motion presentation method than the side-by-side method. This was true for simple geometric forms as well as for complex, "high visual noise" photographs. The average time and average omission errors (for the three experiments) are shown in Figure 9. Table III gives the average number of commission errors per subject per picture.

Table III COMMISSION ERRORS FROM DETECTION OF CHANGE EXPERIMENTS A, B, AND C

	METHOD		
	SIDE BY SIDE	OVERLAY	APPARENT MOTION
Simple Geometric Forms, n = 64	0.1	0.2	0.1
Photographs With Limited Visual Noise	0.1	1.2	0.5
Photographs With High Visual Noise	0.4	0.8	0.7

Values = Average number of false reports per picture per observer.

The overlay method yielded overall inspection times comparable to the apparent-motion method and, for geometric stimuli, a comparable proportion of current detections. However, the overlay method yields considerably fewer correct detections than the apparent-motion method when the changes sought are in aerial photographs. With the aerial photographs, the overlay method also yields fewer correct detections than the side-by-side method. The latter is in sharp contrast with the results for geometric stimuli. The explanation might rest with some observed differences. The bas-relief and Titchener's scintillation effect were observable with the geometric stimuli but were seldom if ever seen with the photographs. Also, a high frequency of meaningless shapes was observed that obscured the relevant changes.

Experiment D

The fourth experiment on efficiency in the detection of change compared the performance of non-photointerpreters and photointerpreters on "high visual noise" serial photographs for the side-by-side and apparent-motion methods of presentation.

Nine photointerpreters of the United States Army from Fort Lewis, Washington, participated as observers. The non-photointerpreters were nine Boeing employees selected only as having adequate visual performance at 21.5 inches from the eye. Each photointerpreter was paired with a non-photointerpreter by random assignment, and each pair worked with the same photographs under the same conditions.

DEPENDENT MEASURES

DETECTION TASK
TIME, OMISSION AND COMMISSION ERRORS

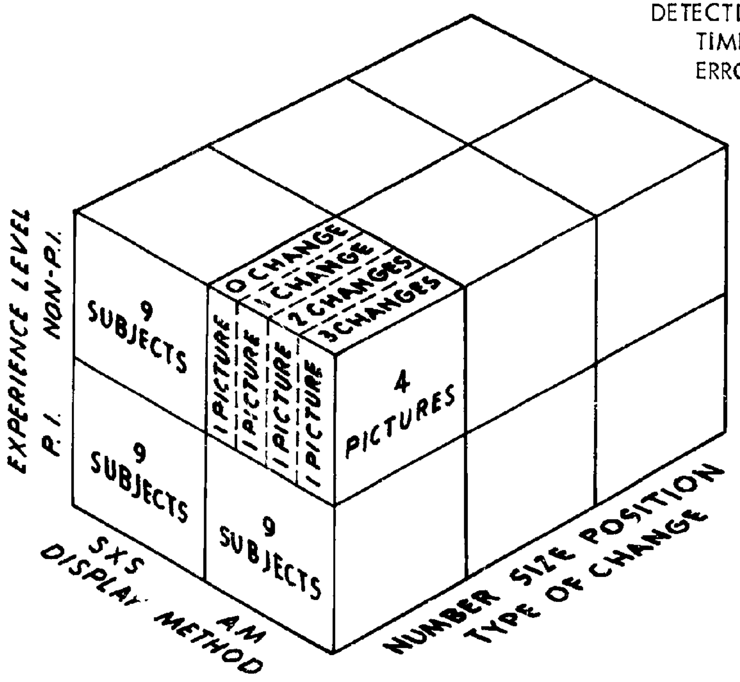


Figure 8 EXPERIMENT D: DESIGN

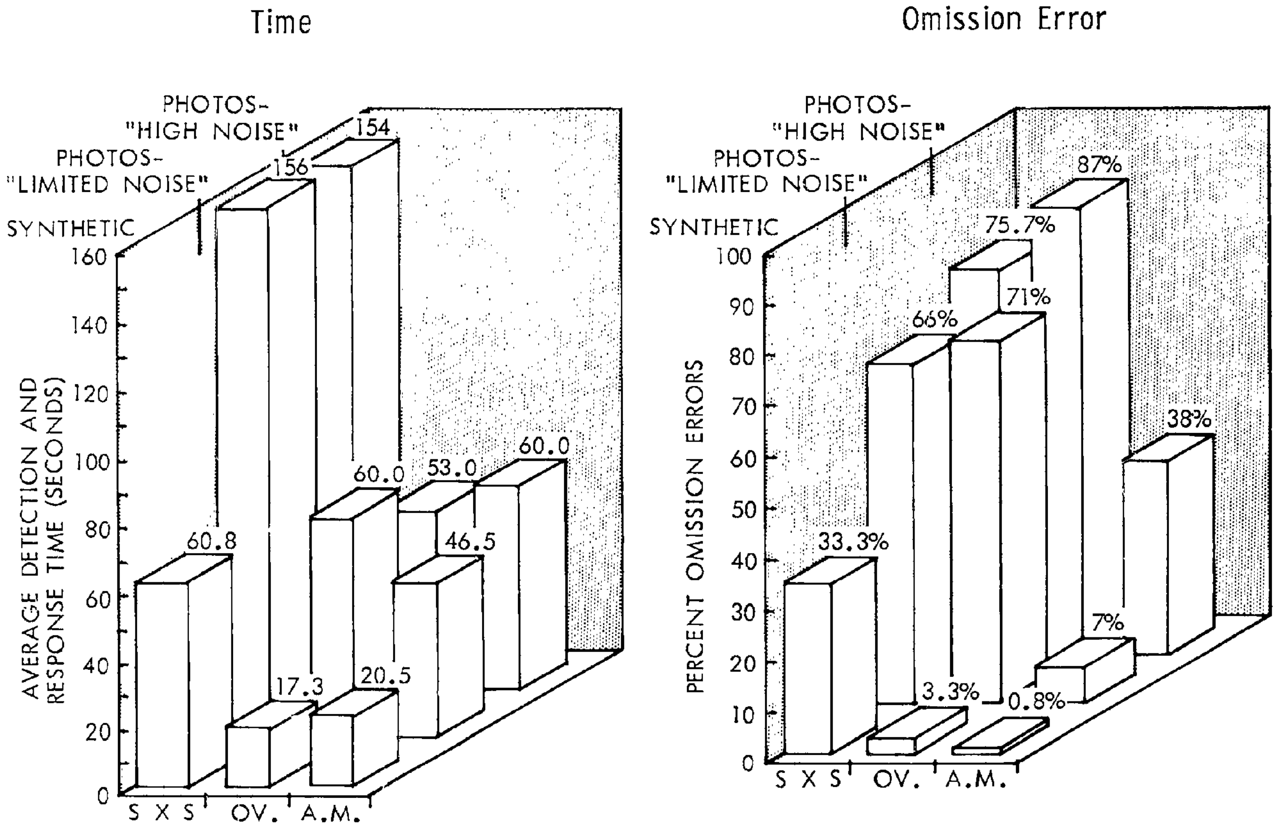


Figure 9 SUMMARY BAR GRAPH OF RESULTS FROM EXPERIMENTS A, B, & C

A 2 by 2 by 3 design was used in this experiment (Figure 8) — two levels of interpreter experience, two display methods, and three types of changes. All 36 "high visual noise" photographs were used although any one oberver saw only 24, 12 under each display condition. All 18 obervers made observations under both display conditions as well as all types and numbers of changes.

The photointerpreter mean performance on the detection of change task was not statistically significantly faster or more accurate than the non-photointerpreters for either the side-by-side or the apparent-motion methods (Table IV); seven of the nine non-photointerpreters equaled the performance of the photointerpreters on the detection of change task. This suggests the hypothesis that, in the detection task, semitrained persons are comparable to photointerpreters.

Table IV MEAN PERFORMANCE OF NON-P.I. AND P.I. IN DETECTING CHANGE IN COMPARATIVE-COVER PHOTOGRAPHY

	SIDE-BY-SIDE		APPARENT MOTION	
	TOTAL TIME SECONDS	OMISSION ERRORS (PERCENT)	TOTAL TIME SECONDS	OMISSION ERRORS (PERCENT)
Photointerpreters	99.8*	75.9*	61.3*	34.0*
Non-Photointerpreters	161.9	77.8	63.8	41.3

* No significant difference between photointerpreters and non-photointerpreters as indicated by Mann-Whitney U Test.

Values are mean per subject per photograph.

These four experimental studies yield quantitative estimates of the relative effectiveness of the standard side-by-side method for detecting change in comparative-cover photography. These data were gathered under conditions similar to the operational method of comparing aerial photographs. Operational techniques differ principally in the degrees of freedom available to the interpreter (i.e., group discussions, varying the viewing distance, and physical measurements on the transparency or print). The influences of these freedoms are not quantitatively known, but they would undoubtedly limit generalizations from the present data.

Because the task of detecting changes should have been relatively easy (the only differences between pictures were the target changes to be reported, with no irrelevant "noise"), the high percentage of omission errors (66 percent) with the side-by-side method is disturbing. That is, according to the apparently reasonable assumption that the operational task is yet more difficult, the error rate is surprisingly high. If, as it appears, our estimate of 66 percent omission errors is conservative, efforts to reduce this error would be well spent. The conservativeness of this estimate is supported by a 10-percent increase in omission errors as a function of the introduction of "noise" associated with a difference in camera angle of 58 degrees. Additional errors would be anticipated with differences between images related to atmospheric effects, seasonal changes, film-processing changes, and equipment malfunctions.

SUMMARY OF RESULTS AND CONCLUSIONS

The quantitative information provided by these four experimental studies indicates that:

1) The effectiveness of the operational or customary side-by-side method of displaying photographs for the detection of change can be measured, and it can be compared with other display methods. The method of preparing stimuli by introducing controlled changes in aerial photographs, or the use of synthetic stimuli, provides a zero reference or a base against which to evaluate interpreter responses. Such a base or "ground truth" is seldom, if ever, found in operational reconnaissance, especially in time of war. To have an absolute criterion makes it possible to have a measure of completeness or a proportion of the changes detected to the changes introduced. This completeness score was 66 percent for synthetic stimuli of low complexity, 33 percent for "low noise" aerial photographs, and 24 percent for the "high noise" photographs. The latter score of 24 percent was the completeness score found for both the non-photointerpreters and the photointerpreters.

2) The display method can significantly affect man's performance in detecting change. In all four experiments, a significant improvement in inspection time and performance completeness was demonstrated with the apparent-motion display method. With only a single exception (overlay method versus apparent motion for synthetic stimuli of low complexity), the apparent-motion method proved to be significantly faster than the other display methods: in every comparison, the detection of change reports were more complete. The apparent-motion method proved better than the side-by-side method in completeness (99 percent versus 66 percent) when the stimuli were of low complexity. This difference increased slightly as stimulus complexity and "visual noise" increased.

3) The experience level of the observer was not a significant factor in the task of detecting change in comparative-cover photography. In the detection of change task, the professional training and experience of U.S. Army photointerpreters did not significantly help them in detecting changes in aerial photographs with either the side-by-side or apparent-motion display methods when their performance was compared with observers trained only to use the specific displays.

4) The positive-negative overlay method was not an improvement over the standard method of displaying aerial photographs for the detection of changes. This method — one that appears most applicable to machine usage — is not an effective method of displaying for man's discrimination the comparative-cover photographs of high complexity and of many gray steps. When the photographic stimuli are regular configurations of low complexity and few gray steps, the overlay method is a significant improvement over the side-by-side display method. The explanation offered for this difference in performance with simple and complex stimuli is that the perceptual phenomena that assist in the low-complexity discrimination are not available to the observer when working with stimuli of high complexity. The "silvery" appearance of Titchener's scintillation effect, and the bas-relief effect, both associated with unchanged areas, were ineffective with the complex stimuli. In addition, changes are masked by the positive-negative interaction that produces unusual and meaningless shapes.

5) A number of conditions are related to man's performance in detecting changes in aerial photographs. In low-complexity stimuli, changes in the 16-minute (visual angle) and 32-minute-sized squares were found significantly faster than the same kinds of changes introduced in the 4-minute-sized objects. (The performance in detecting change did not differ significantly for the 16-minute objects when compared with the 32-minute objects.) In these instances, the changes were half the length of the side of the square targets. For the low-complexity stimuli, the types of changes in their order of difficulty were position, size, and addition. No significant differences were found among these types of changes when they occurred in the aerial photographs. Orientation of the slide did not significantly change performance. Each of the differences mentioned above was found to be significant at or below the 0.01 probability level.

The value of stimulus parameters that were held constant in this former work are given below for reference. The rate of alternation in the apparent-motion display was always 1.5 cps, where one cycle is the successive presentation of both members of the pair. The photograph as presented to the observer was always a 4-inch by 4-inch square. The aerial photographic display scale was 1:14,496, and only transparencies were used. The changes in the photographs were all within 16 to 32 minutes of visual angle. The original quality of the aerial photographs was excellent, and the observers saw fourth-generation reproductions of these photographs. No special treatment of the stimuli was made in changing and matching along the dimensions of magnification or rectification. Registration in X and Y coordinates was as good as could be accomplished with hand mounting and visual matching. The magnitude of registration errors was later measured, and was as shown in Table V.

Table V REGISTRATION ERRORS MADE IN MOUNTING THE 144 TRANSPARENCIES, FOUR FOR EACH OF 36 PAIRS Used As Stimuli In Experiments A, B, And C

	REGISTRATION ERRORS IN MILLIMETERS WHEN MATCHED TO MASTER OF EACH PAIR			
	Mean in X	SD in X	Mean in Y	SD in Y
Negatives	-0.029	0.232	+0.044	0.162
Positives (Low Noise)	-0.031	0.254	+0.072	0.161
Positives (High Noise)	+0.079	0.335	+0.003	0.361

OBJECTIVES OF THE RESEARCH PROGRAM

The importance of the reconnaissance system as a primary source of information has been discussed in the initial pages of this report. The speed with which this information system must react has been gaining emphasis with each new ballistic weapon development. The potential now exists for any power to inflict major destruction on an adversary within three quarters of an hour from its first war-like act. Reconnaissance system reaction time must be faster than this strike time. This intensification of the requirement for speed has brought into even sharper contrast the performance of the interpretation, classification, and encoding subsystems with those of collection, storage, and retrieval.

This need for speed and accuracy has re-emphasized the magnitude and the immediacy of the need to increase the flow of information through the reconnaissance-intelligence system.

The research reviewed in the preceding pages was directed at this specific problem area, but has not provided sufficient definitive data on the limited subject of the human observer's performance in detecting changes in comparative-cover photographs. The U.S. Air Force has pointed out broad areas that have not been investigated. They indicated that research data did not exist to permit an adequate prediction of the photointerpreter's performance with different qualities of photographs, for different parts of the reconnaissance job, with current or new equipment, or whether current training procedures were adequate.

This research program, then, was designed to provide new data on photointerpreter performance as a function of those variables that appeared most important and susceptible to quantitative manipulation. The objective of the program was to determine the effects of selected variables on the performance of photointerpreters in accomplishing the tasks of screening and identifying target changes when the side-by-side and apparent-motion display methods are employed in presenting comparative-cover aerial photographs.

The variables selected for investigation include:

1) Display method;
2) Photointerpreter experience level;
3) Contrast;
4) Image quality;
5) Photographic scale;
6) Terrain complexity;

7) Relevancy of changes:
8) Time lapse between photographs:
9) Types of change:
10) Real versus artificial changes.

The procedural steps in implementing this program were: (1) to obtain, with the assistance of the Air Force, samples of comparative-cover photography that were representative of military and civil reconnaissance pictorial data, (2) to conduct three major experiments to determine the effects of the above variables on photointerpreter performance with the two display methods in the tasks of screening and identifying change, and (3) to evaluate the significance of the experimental data with respect to the relative advantages and disadvantages of the two methods of display as well as provide recommendations for future investigations. Common to the three experiments are the primary variables of display method and photointerpreter experience level. These variables and the other selected variables were apportioned as shown in Table VI.

Table VI SELECTED VARIABLES APPORTIONED BY EXPERIMENTS

VARIABLES	EXPERIMENT I	EXPERIMENT II	EXPERIMENT III
1. Display Method	S x S AM	S x S AM	S x S AM
2. Photointerpreter Experience Level	P.I. Non-P.I.	P.I. Non-P.I.	P.I. Non-P.I.
3. Contrast	20, 40, 60%		
4. Image Quality		High, Med, Low Acutance	
5. Photo Scale		1:10,000 1:20,000 1:40,000	
6. Terrain Complexity		Industrial, Suburban, Rural	
7. Relevancy of Change	Yes	Yes	Yes
8. Time Lapse Between Photos			5, 10, 15 months
9. Types of Change	#, Size, and Position		
10. Real vs. Artificial Changes		Natural vs. Artist Inserted	
Tasks			
Detection	Time, % Correct, and Com Errors		Time, % Correct, and Com Errors
Identification	Time and % Correct		

EXPERIMENT I

INTRODUCTION

The experiments described in this section and those that follow are a direct extension of a continuing program of a reconnaissance study program conducted in the Engineering Psychology Laboratory at The Boeing Company. The goal of this research program is to provide information applicable to the design and evaluation of display systems for faster, more accurate, and more complete information extraction from comparative-cover aerial photography than present systems provide.

In addition to greater speed and accuracy, a better display will require less training for efficient observer performance. Considerable economy might be realized if inexperienced observers are able to detect changes and at least roughly classify them, allowing photointerpreters to spend more time on more complex interpretation. The only way to evaluate the inexperienced observer in this situation is to compare his performance with experimental displays to the performance of trained photointerpreters with the same equipment. Photointerpreters and non-photointerpreters were used in each experiment.

The quality of the imagery received by the photointerpreter in operational situations varies widely from sample to sample. One such dimension of quality is film contrast. Film contrast is distinguished from inherent target contrast, which refers to the differences in film density arising from reflectance differences of the target object and its immediate surroundings. Film contrast in any sample photograph depends variously on such things as the sensitivity of the emulsion, and the development and reproduction procedures.

Experiment I investigated the effects of three levels of contrast on the detection and identification of change. Through the systematic introduction into the photography of changes in target size, position, and number (additions or subtractions), "absolute ground truth" was established for the test imagery. This made is possible to determine empirically the probabilities of detecting and identifying each of these types of change as affected by various combinations of viewing condition, image quality, and observer experience.

Briefly summarized, the objectives of Experiment I were to determine the accuracy, completeness, and speed with which photointerpreters and non-photointerpreters can detect and identify changes of number, size, and position occurring in comparative-cover aerial photography of three contrast levels when these photographs are displayed in side-by-side and apparent-motion formats.

SUBJECTS

Although the goals of the study involved generalization of the results to Air Force photointerpreters, no feasible approach for sampling this population could be found. A compromise was made. Through a request placed in the weekly Boeing newspaper, 60 Boeing employees were found who had received training and/or experience in photointerpretation, although they were not currently engaged in it. A brief summary of the training and experience of those who served on a volunteer basis in this research program is contained in Appendix I. It can be seen here that, although 12 out of the 21 persons in this group had received their training and gained their experience in a military setting, training of others was obtained as part of an academic program and whose experience with aerial photography was gained in the course of such duties as cartographers, photogrammetrists, foresters, geologists, and surveyors. Although the amount and specific orientation of the training and experience represented in this group is quite heterogeneous, they all possess one common element; they are all familiar with the use of aerial photographs for the detection, localization, and identification of ground objects. The members of this subject sample were designated the "photointerpreters" with the expectation that their performance under the different experimental treatments would provide some approximation of what might be expected from a sample of currently active military photointerpreters. Twelve of these subjects constituted the photointerpreters in Experiment I.

A second group of 12 observers (the "non-photointerpreters") was selected from the Bioastronautics organization of The Boeing Company. Approximately equal proportions of shop technicians, laboratory technicians, and junior and senior research personnel were represented. Only those persons who: (1) had no training or experience in photointerpretation, (2) had not participated in any of the previous experiments in the reconnaissance program conducted by the Engineering Psychology Unit, and (3) did not demonstrate any limiting visual defects or weaknesses were considered for inclusion in this group.

TRAINING

Prior to the beginning of the first experimental session, each subject was trained on the response and reporting procedures for both display methods. The training program consisted of presenting each subject with a series of training slides that were graded in difficulty.

The first set of six pairs of training slides each contained 64 randomly positioned white squares against a black background. Within this set of slides, three types of change (number, size, and position) were equally represented and the number of changes per slide pair varied from zero to six.

The second set of training materials consisted of six pairs of comparative-cover aerial photographs that were described as "minimum visual noise" photographs in a preceding section of this report. These comparative pairs were simply two prints from the same negative with only a small number of target objects artistically added or changed. Changes again represented all three classes and varied in number per pair to prevent the observer from developing a response set.

The final set of training slides in the series consisted of six samples of comparative-cover aerial photography taken on the same pass and represented a viewing angle separation of approximately 58 degrees. As in the above-mentioned slides, each of the three types of change was represented. and the number of changes per comparative pair was varied.

The instructions (see "Instructions" below) were to detect and report all changes existing between the two photos of each comparative pair. Knowledge of results and instructional comments were provided by the experimenter at each step of the training procedure. All questions were answered directly by the experimenter if the answer would not bias or invalidate the subject's performance during the remainder of the testing.

Previous studies had demonstrated that this training program was adequate to minimize both target localization error and response time attributable to lack of familiarity with the equipment.

INSTRUCTIONS

The following instructions were presented during the training session.

> "Please give your full attention to the following instructions: The primary purpose of this investigation is to evaluate the relative merits of two different display techniques.
>
> "The material to be displayed is comparative-cover aerial photography from which intelligence information is to be extracted. Comparative-cover photography consists of two pictures of the same area taken at two different times. The 'intelligence information' that we are asking you to look for is represented by the changes which have occurred between the time of the first and the second photograph.
>
> "The two display techniques being evaluated are referred to as the 'side-by-side' method, in which the two pictures are presented simultaneously in adjacent positions, and the 'apparent-motion' method, in which the two pictures are rapidly alternated in the same location so that those objects which are the same in both pictures remain relatively stationary while those objects which have changed appear animated or in motion.
>
> "You have been asked to serve as an observer or photointerpreter in this research program to provide the performance data which will allow us to make the desired evaluation of these two display methods. As an observer

in this first experiment you will be asked to serve on four separate occasions, each lasting approximately one hour. During this first session you will be given training on both of the display techniques and will be taught to use the response system which we have designed to obtain our performance measures. In the remaining sessions you will be asked to view a number of aerial photographs under each of the display methods and to report the location of changes which have occurred between the two photographs in each comparative pair.

"We will now begin by teaching you to use the response system. First, take this shutter-activation switch in your left hand. By pressing the button on the top of this handle you can open the shutter in the display apparatus thereby letting you view the photographs displayed inside. During the remainder of this training session and during the subsequent testing, any time you wish to look at the photographs you simply press this shutter switch. Although we do not have any pictures displayed in the box now, you can try activating the shutter a few times to see how this component operates.

"Now if you will open the shutter again we will continue on to the next step. By looking through the viewing aperture you will be able to see a 4" x 4" square of light. Later in the training, aerial photographs will be seen in this area during the 'apparent-motion' presentation. With the 'side-by-side' presentation two such areas, one slightly to the left of center and a second slightly to the right of center, will be seen.

"The response panel, which you will use to indicate the areas in which you detect a change, is located here on your right. You will notice that the 36 pushbuttons located on the response panel are arranged in a square; six rows and six columns. Each of these pushbuttons corresponds to a different portion of the photograph. When any one of these buttons is depressed a small light appears in the corresponding position over the photograph. For instance, pressing the button in the upper left of the response panel causes a light to appear in the upper left corner of the photograph (or, since there is no photograph in the system now, over the light square).

"Press a few of the buttons now to see how this feedback system works, but do not hold the buttons down for more than a half second. If you hold a button down for over one-half second the small single light disappears and a 'light veil' comes on over the whole area except over the area in which the single light originally appeared and the three immediately adjacent sections. This will permit you to continue looking at only this area without being distracted by other things in the picture.

"Try it a few times now. You will notice that when you release the button the shutter closes over the viewing aperture. You can open the shutter again by depressing the shutter activation switch with your left hand.

"The one-half second delay between the pressing of the button and the illumination of the veiling mask is included to allow you ample opportunity to change your response as many times as necessary until you have pressed the right button: that is, the button which corresponds to the area on the photograph which contains the change you have detected and wish to report.

"Now to give you some experience in using the response panel and to introduce you to what different types of changes look like with the two different display techniques, I will show you some pictures containing a collection of white squares on a black background. Represented on these pictures are three kinds of change: changes in size, where a square has been made larger or smaller; changes in number, where a square has been added or removed; and changes in position, where a square has been shifted (either vertically or horizontally) or rotated.

"It is your task to search these pictures for the differences that exist between the two photographs. As soon as you detect a change, either in size, position, or number, press the button which illuminates the light over that area on the picture. Hold the button down and verbally report the kind of change which is represented. Then release the response button. When you are ready to continue the search open the shutter with the left hand switch and continue the search. Repeat this procedure until you are satisfied that you have detected each and every change which exists on the photographs. When you are sure that you have reported all the changes, press the small red button on the right side of the response panel. This button signals the completion of search for that picture pair. The experimenter will then tell you how well you have performed and will insert a new set of photographs."

After this series of photographs was completed, the following instructions were given.

"The next series of photographs you will be shown are aerial photographs taken between Baltimore and Washington, D. C. These particular photographs are in a class which we call 'low noise' since both pictures were taken from the same point in space. Furthermore, the second picture was taken very shortly after the first was taken so that they are very similar in every respect (such as shadows).

"In viewing these photographs you will report the location of the changes you detect in the same way that you did with the preceding material, that is, by pushing the button which corresponds to the area of change in the photographs. You are also required to tell the type of change which you have found. In addition to the location and type of change you will now be requested to identify the object which has changed. It may be a building that has been enlarged or an oil tank which has been added or a ship which has moved from a dock. Be sure you have found all the changes before you signal for the next set of pictures."

After this series of photographs was completed, the following instructions were given.

> "This last set of pictures is very similar to those which you have just been looking at. The main difference is that whereas the previous pictures were taken from the same point in space, these pictures were taken from slightly different places. It is as if the airplane taking the picture was not able to fly exactly the same flight path on successive missions and so the object on the ground is photographed from slightly different angles. Although all objects on the ground will look a little different on each of the pictures of a pair only those objects which have definitely been changed are to be reported. The reporting procedure will be the same as that which you used with the 'low noise' material."

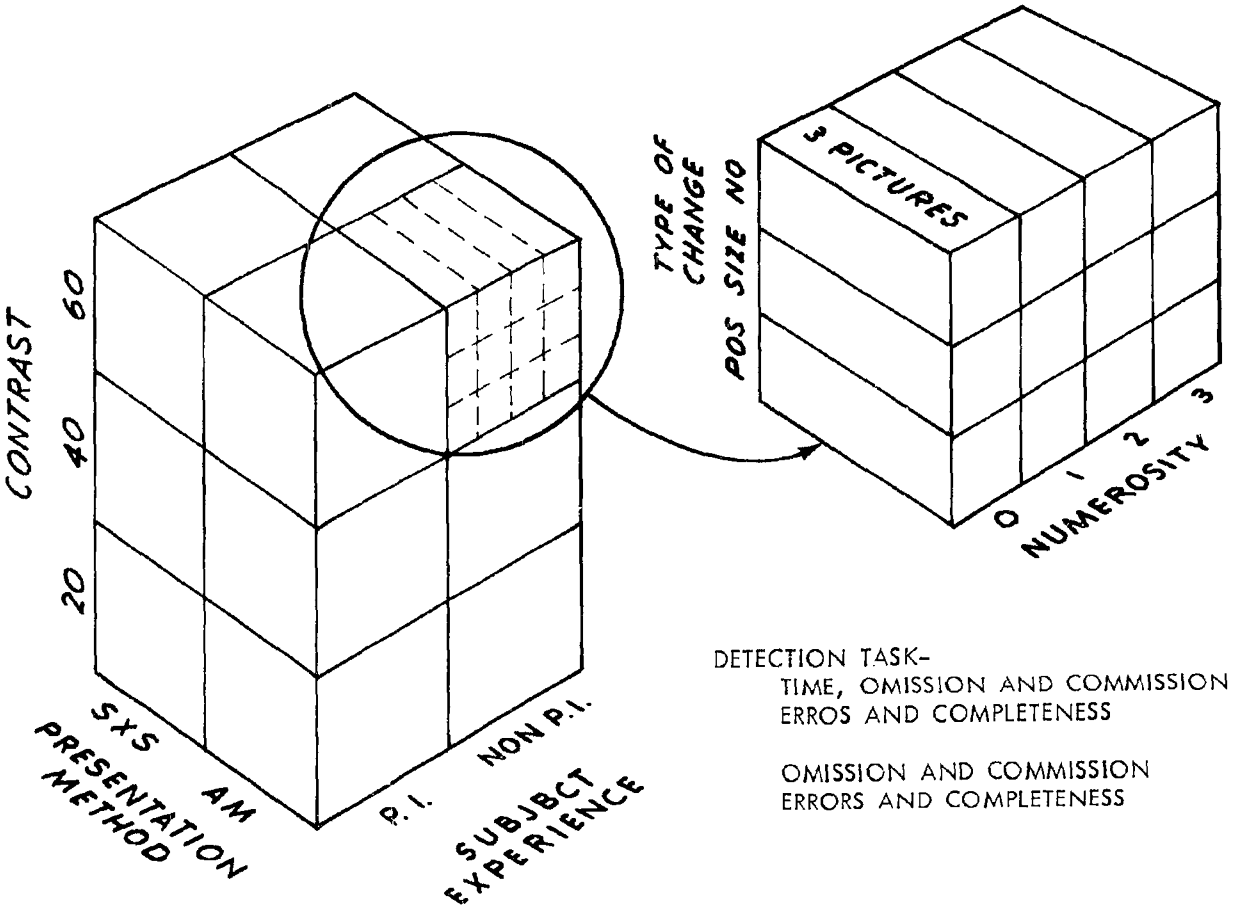
Before the first test session was begun, a brief review of the response system was given, and the following instructions were presented.

> "Before beginning it is important that you understand how your performance is being evaluated. We are interested in three aspects of your performance: the SPEED with which you can detect the changes; your ACCURACY in reporting the location, kind of change and object changed; and how many real changes you can detect. We are equally interested in all three measures: SPEED, ACCURACY and COMPLETENESS. Since there may be some picture pairs which contain no changes and others which contain several changes you are cautioned to be relatively certain of your decisions before you respond. To call something a change when it is <u>not</u> really changed is as bad as not detecting a change which <u>is</u> present.
>
> "We are now ready to begin. Do you have any questions?"

DESIGN

The independent variables in this experiment were: (1) presentation method — side by side and apparent motion, (2) experience level of interpreter — inexperienced and experienced, (3) relative film contrast — 20, 40, and 60 percent, and (4) type of target change — number, size, and position. A schematic representation of the treatments and treatment levels is shown in Figure 10. The dependent measures were: (1) inspection time, (2) number of correct detections and identifications, and (3) errors of commission.

The design chosen for measuring differences between the respective levels of contrast and the two display methods was one in which all twelve observers in each group (experienced and inexperienced) received all six combinations of experimental treatments. All six permutations of the three contrast levels were used twice (once side by side and once in apparent motion) for each group of subjects.



DETECTION TASK–
TIME, OMISSION AND COMMISSION
ERROS AND COMPLETENESS

OMISSION AND COMMISSION
ERRORS AND COMPLETENESS

Figure 10 EXPERIMENT I: DESIGN

Each subject viewed each of 36 comparative pairs. He inspected 12 scenes in each of three experimental sessions. Six of the scenes presented in each session were displayed in side-by-side format and six in apparent motion. Each of the three types of target changes was represented in the comparative pairs seen during each session.

Each session required between 40 and 70 minutes, a length that appeared to be most efficient without tiring the observer.

The analysis was conducted as if the design were a completely replicated (12 times) factorial arrangement. Because of the repeated measures on the same subjects, it was anticipated that the statistical significance of obtained treatment differences might be somewhat enhanced. However, the careful balancing of the treatment assignments was expected to minimize this effect.

EQUIPMENT

The display equipment was the same as that shown in Figure 2, but with two modifications.

The first modification was made to introduce the three levels of contrast reduction. A new two-way mirror was installed that had a good color balance and provided 30-percent transmission, 30-percent absorption, and 30-percent reflectance. Contrast was varied through the addition of a fourth optical pathway (Figure 11). A plate-glass surface just in front of the eyepiece, and inclined 45 degrees to the line of sight, reflected the light coming from a diffuse "cold light" source. Neutral-density filters were placed between the light source and the reflecting plate glass to change the intensity of this glare source. Compensating filters were introduced just after the conical shutter (Figure 11) to maintain a constant illuminance level at the eye.

The 100-percent contrast condition was 10 foot-candles of illuminance for each major beam without the slide in its holder. The 60-, 40-, and 20- percent contrast conditions were effected by the substitution of 4, 6, and 8 foot-candles of glare-source illuminance for the same quantities of beam illuminance. The measurements of illuminance were made at the eyepiece with a MacBeth illuminometer.

The second modification of the equipment involved a redesigned response-feedback channel to obtain independent measures of detection and identification time. In the description of this feedback channel (Page 11), the individual-response pushbuttons for indicating target location (those in the 6 by 6 matrix) were in a normally open circuit with a corresponding 6 by 6 matrix of lights. As the observer indicated the location of a change, one of these lights was turned on and became visible to the observer as a glare veiling that one thirty-sixth of the slide corresponding to his response. This same feedback system was maintained in the modification of the equipment with the exception of an increased

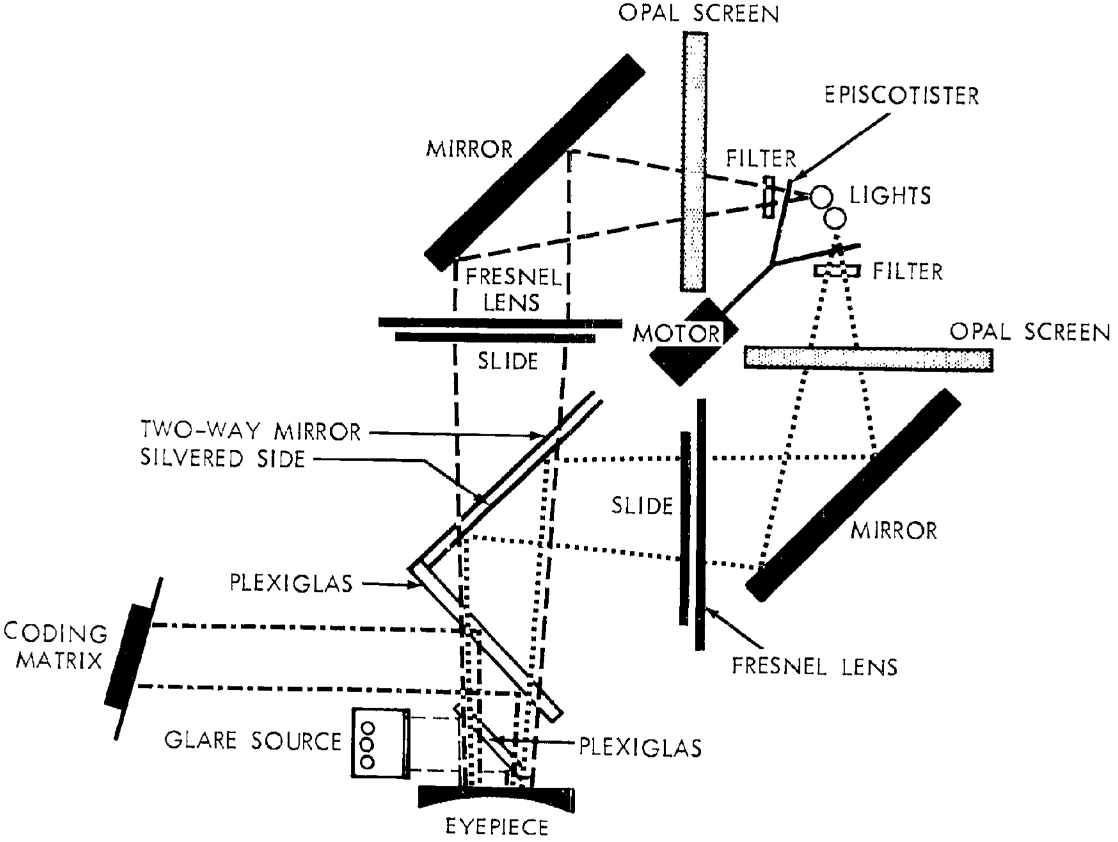


Figure 11 FUNCTIONAL DIAGRAM OF MODIFIED CHANGE-DETECTION APPARATUS

intensity and a diffusion square that was introduced in front of the lamp. This latter changed the shape of the veiling light from a circle to a square about 0.667 inch on a side. The feedback of a detection response looked like that in Figure 12 for the first 0.5 second the button was depressed.

The printer circuit records the elapsed time from the beginning of the exposure to the detection response. With the exception of the square image of the veiling patch for detection response feedback, this response and readout is the same as in previous experiments where the only task was detection.

The method of separating the identification task from the possibility of continued search during the time the verbal response was being given was to obscure all the remainder of the slide except the designated area and three immediately adjacent areas which provided contextual information to aid in identification. Figure 13 illustrates this masking by the occluding veil. The keying circuit selected and switched on the 32 masking lamps 0.5 second after the detection response if the key was maintained in the depressed position by the observer. The observer could, as before, change his response within this 0.5-second delay interval without the printer recording the nonintended response.

During his reporting of the identity and type of change, the observer maintained the depressed position of the response key. Release of this key activated the printer to record the termination time of the identification response. The observer repeated the sequence of operations by: (1) opening the shutter to begin the trial, (2) detecting a change, (3) depressing the response key, (4) holding the key during identification, and (5) releasing the key, until he had responded to all changes seen in the photographs. The observer indicated that he had completed his inspection by pushing a final button that recorded total inspection time on the digital printer.

STIMULUS MATERIALS

The stimulus materials were the same as those in Experiments C and D reported in the "Introduction," as well as the detailed information in Appendix II.

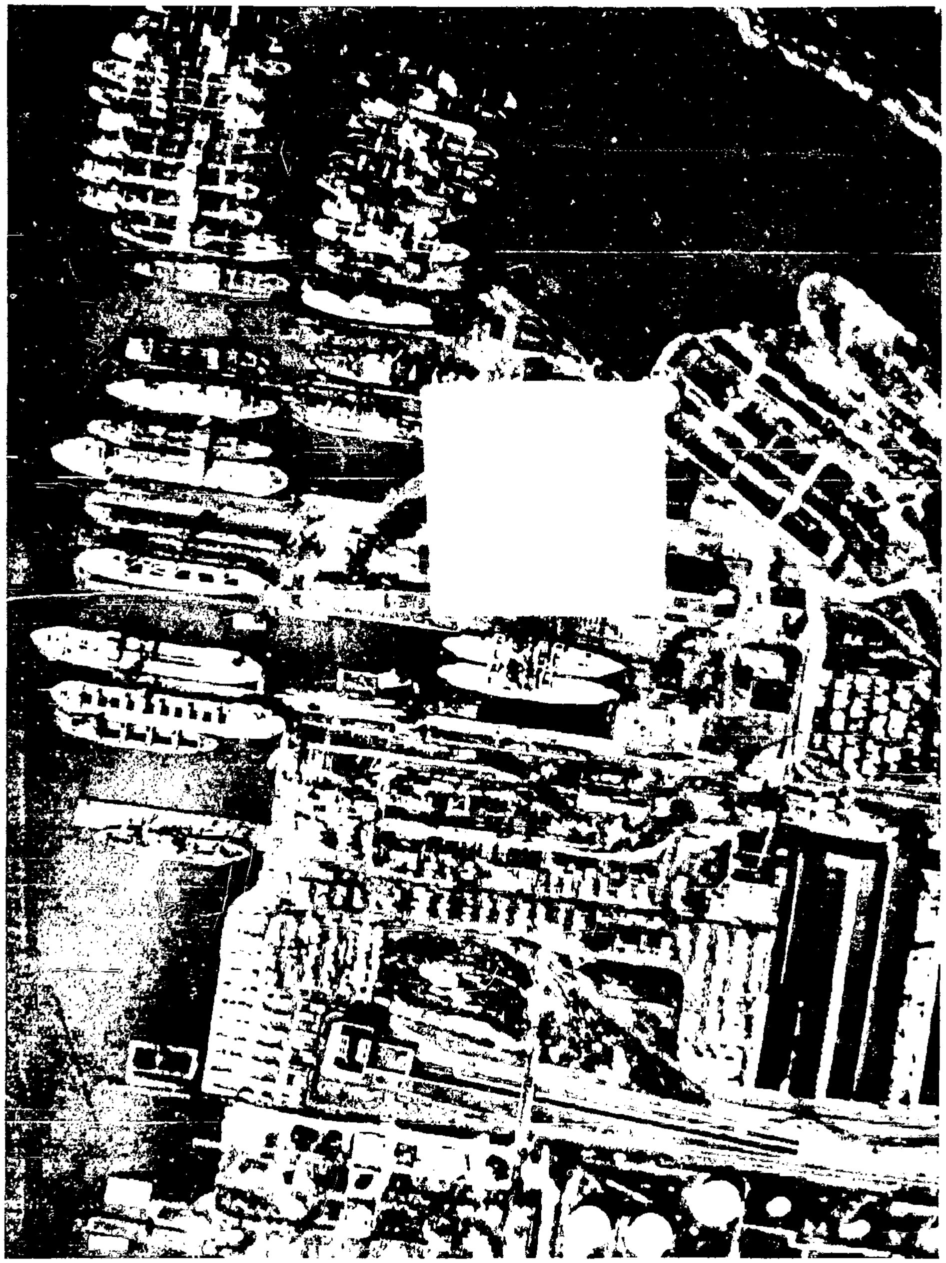


Figure 12 FEEDBACK IN FIRST 0.5 SECOND OF A DETECTION RESPONSE

Figure 13 MASKING VEIL FOR ISOLATION OF AN AREA DURING IDENTIFICATION RESPONSE

RESULTS

The dependent measures available for analysis include the number of targets correctly detected, the number of detected changes correctly identified, inspection time required for detection, inspection time required for identification, and the number of commission errors elicited. These performance measures are summarized for each treatment and treatment level in Table VII. Because absolute ground truth (number of changes) was known, both detections and identifications are expressed as percentages that are interpretable as indices of completeness.

To aid the reader in integrating performance levels across experimental conditions, these data are presented graphically in Figures 14A through 14G.

The first analysis performed was to evaluate the effects of the various treatments on the number of changes detected. This measure involves only the correct report of the location of a change and is considered independent of whether the subsequent identification was correct. The analysis of variance is summarized in Table VIII(A) and reveals:

1) A significantly larger number (p less than 0.01) of changes were correctly detected with the apparent-motion display system (39.0 percent) than with the side-by-side presentation (17.0 percent).

2) Photointerpreters did not detect a significantly greater or fewer number of changes than did the non-photointerpreters.

3) The number of changes correctly detected (p less than 0.01) was significantly influenced by the contrast level of the imagery. Only 13.2 percent of the changes were reported when the film contrast was 20 percent, whereas 30.8 percent were correctly detected with the 40 percent contrast material, and 40.0 percent were detected with the highest contrast (60 percent) imagery. Duncan's New Multiple Range Test (Edwards, 1960) was applied and revealed significant performance differences between each contrast level.

4) A significant interaction (p less than 0.01) between display methods and contrast level was found to exist. By inspecting the curves presented in Figure 14(A), it can be seen that, whereas detection performance with the apparent-motion display increases almost linearly as contrast improves, the performance levels with the side-by-side display does not improve for contrasts above 40 percent. Critical ratios computed on the performance differences between successive contrast levels reveal significant increases (p less than 0.01) with each improvement in contrast for the apparent-motion method and a significant improvement only between the 20- and 40-percent contrast levels with the side-by-side display.

Following each report of a detected change, subjects were required to identify the object that had been changed and to specify the type of change (i.e., number,

Table VII
TABLE OF MEANS FOR EXPERIMENT I

(A)

PERCENT OF TARGETS CORRECTLY DETECTED

	20% CONTRAST		40% CONTRAST		60% CONTRAST		
	AM	SxS	AM	SxS	AM	SxS	MEANS
Non-P.I. Group	17.5	8.3	42.6	24.1	63.9	20.4	29.47
P.I. Group	17.5	9.3	40.7	15.7	51.8	24.1	26.52
MEANS	13.15		30.77		40.05		

(B)

PERCENT OF TARGETS CORRECTLY IDENTIFIED

	20% CONTRAST		40% CONTRAST		60% CONTRAST		
	AM	SxS	AM	SxS	AM	SxS	MEANS
Non-P.I. Group	12.0	4.6	32.4	17.6	50.0	16.7	22.22
P.I. Group	13.9	7.4	33.3	14.8	46.3	20.4	22.68
MEANS	9.49		24.54		33.40		

(C)

PERCENT OF DETECTIONS CORRECTLY IDENTIFIED

	20% CONTRAST		40% CONTRAST		60% CONTRAST		
	AM	SxS	AM	SxS	AM	SxS	MEANS
Non-P.I. Group	68.4	50.0	76.1	65.4	78.3	81.8	70.0
P.I. Group	78.9	88.8	81.8	94.1	89.3	84.6	86.25
MEANS	71.52		79.35		83.50		

Table VII TABLE OF MEANS FOR EXPERIMENT I (CONT.)

(D)

MEAN DETECTION TIME PER PAIR (SECONDS)

	20% CONTRAST		40% CONTRAST		60% CONTRAST		
	AM	SxS	AM	SxS	AM	SxS	MEANS
Non-P.I. Group	130.0	188.2	161.0	217.6	148.2	200.9	174.3
P.I. Group	143.2	182.5	130.6	211.4	137.3	186.0	165.2
MEANS	161.0		181.1		168.1		

(E)

MEAN IDENTIFICATION TIME PER RESPONSE (SECONDS)

	20% CONTRAST		40% CONTRAST		60% CONTRAST		
	AM	SxS	AM	SxS	AM	SxS	MEANS
Non-P.I. Group	4.3	4.6	9.4	9.2	9.6	7.1	7.37
P.I. Group	12.3	10.6	10.1	6.8	10.3	12.3	10.40
MEANS	7.95		8.87		9.82		

(F)

MEAN INSPECTION TIME/PAIR (SECONDS)

	20% CONTRAST		40% CONTRAST		60% CONTRAST		
	AM	SxS	AM	SxS	AM	SxS	MEANS
Non-P.I. Group	139.6	192.4	180.9	226.1	170.3	209.1	186.40
P.I. Group	156.3	188.7	152.9	218.5	162.2	195.0	178.93
MEANS	169.25		194.60		184.15		

Table VII TABLE OF MEANS FOR EXPERIMENT I (CONT.)

(G)

MEAN COMMISSION ERRORS PER PAIR

	20% CONTRAST		40% CONTRAST		60% CONTRAST		
	AM	SxS	AM	SxS	AM	SxS	MEANS
Non-P.I. Group	0.57	0.29	0.99	0.40	1.20	0.49	0.657
P.I. Group	0.50	0.31	1.00	0.35	0.94	0.32	0.570
MEANS	0.417		0.685		0.737		

(H)

	DISPLAY SYSTEMS	
	AM	SxS
Percent Detections	39.00	16.98
Percent Identifications	31.00	13.67
Percent Detections Identified	78.80	77.45
Mean Detection Time Per Pair (Seconds)	141.7	197.7
Mean Identification Time Per Pair (Seconds)	9.33	8.43
Mean Inspection Time Per Pair (Seconds)	160.3	205.0
Mean Commission Errors Per Pair	0.867	0.360

Table VIII SUMMARY OF THE ANALYSES OF VARIANCES
Experiment I

		(A) DETECTIONS		(B) IDENTIFICATIONS	
SOURCE OF VARIANCE	df	ms	F	ms	F
Between Groups (G)	1	2.51	1.45	0.06	0.32
Between Displays (D)	1	146.00	84.39**	91.84	47.43**
Between Contrasts (C)	2	143.00	82.66**	56.66	29.26**
G x D	1	0.34	0.20	0.17	0.09
G x C	2	0.81	0.47	0.27	0.14
D x C	2	20.23	11.69**	12.60	6.51**
G x D x C	2	2.00	1.16	0.75	0.39
Error Variance	132	1.73	—	1.94	—
TOTAL	143				

		(C) DETECTION TIME		(D) IDENT. TIME	
SOURCE OF VARIANCE	df	ms	F	ms	F
Between Groups (G)	1	6,833	2.25	327	4.25*
Between Displays (D)	1	12,027	39.59**	29	0.38
Between Contrasts (C)	2	2,867	0.94	42	0.54
G x D	1	1,921	0.63	0.34	0.01
G x C	2	3,959	1.30	117	1.50
D x C	2	2,324	0.77	8	0.10
G x D x C	2	102	0.04	51	0.66
Error Variance	132	3,038	—	77	—
TOTAL	143				

		(E) TOTAL INSP. TIME		(F) COMMISSION ERRORS	
SOURCE OF VARIANCE	df	ms	F	ms	F
Between Groups (G)	1	72,092	0.31	9.51	1.17
Between Displays (D)	1	2,581,913	11.30**	333.06	41.12**
Between Contrasts (C)	2	280,566	1.20	50.76	6.27**
G x D	1	1,308	0.01	0.34	0.04
G x C	2	67,954	0.29	4.89	0.60
D x C	2	42,622	0.19	24.03	2.97
G x D x C	2	46,223	0.20	0.84	0.10
Error Variance	132	228,731	—	8.10	—
TOTAL	143				

* = $0.01 < p < 0.05$ ** = $p < 0.01$

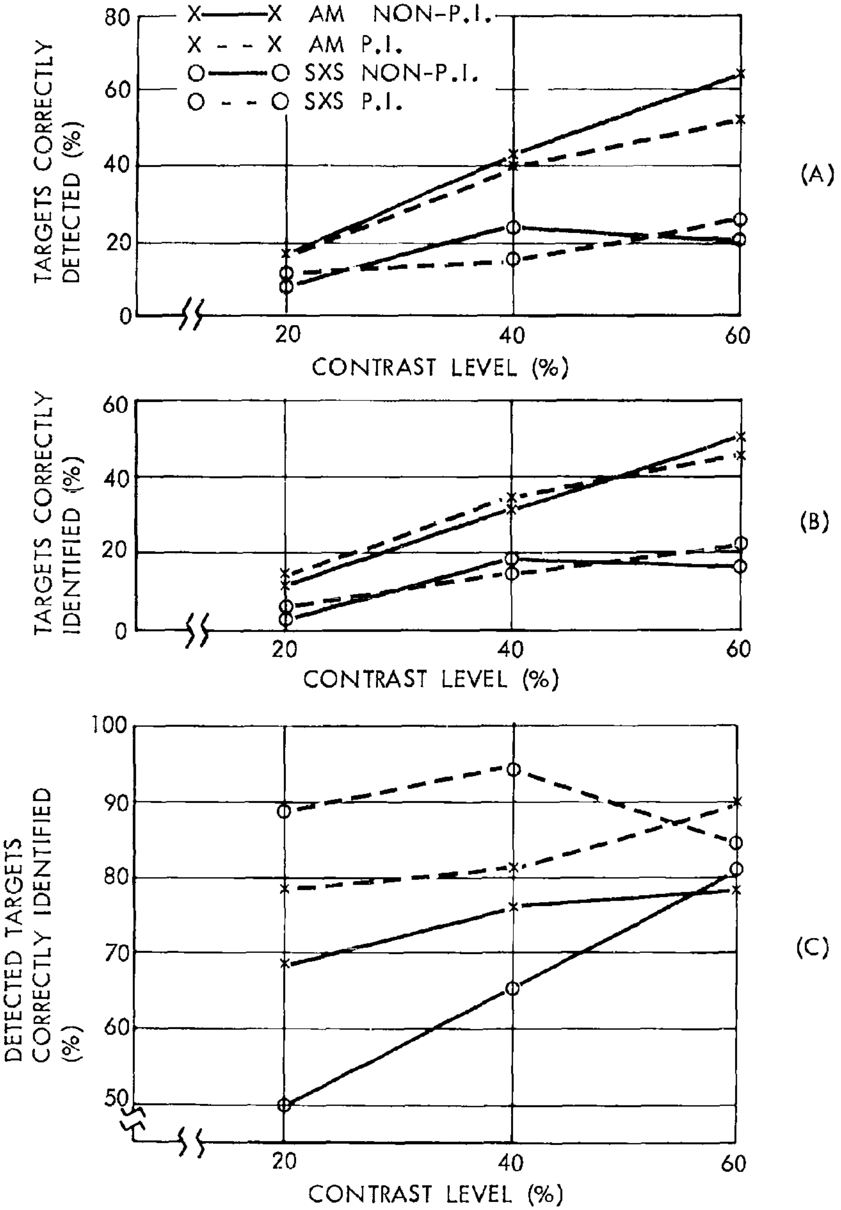


Figure 14 PERFORMANCE AS A FUNCTION OF CONTRAST IN EXPERIMENT I

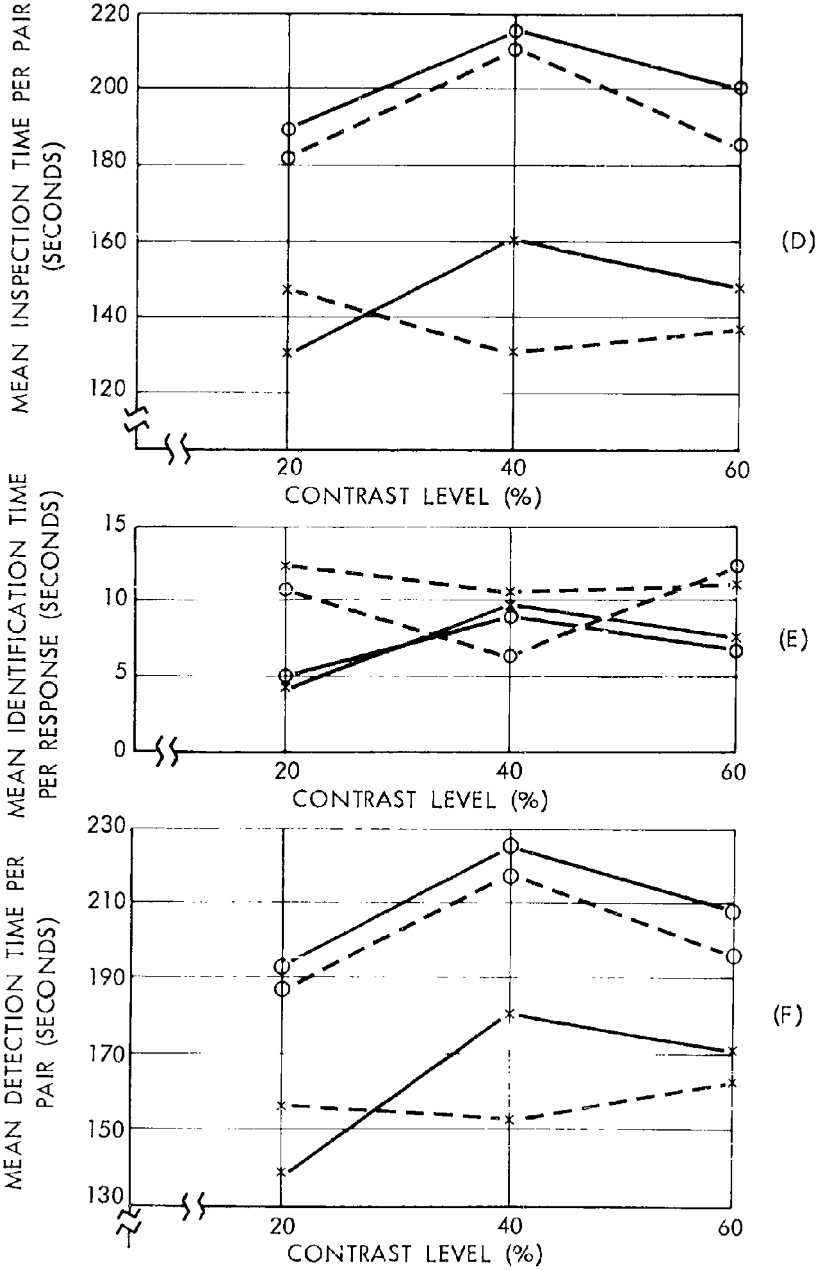


Figure 14 PERFORMANCE AS A FUNCTION OF CONTRAST IN EXPERIMENT I (CONT)

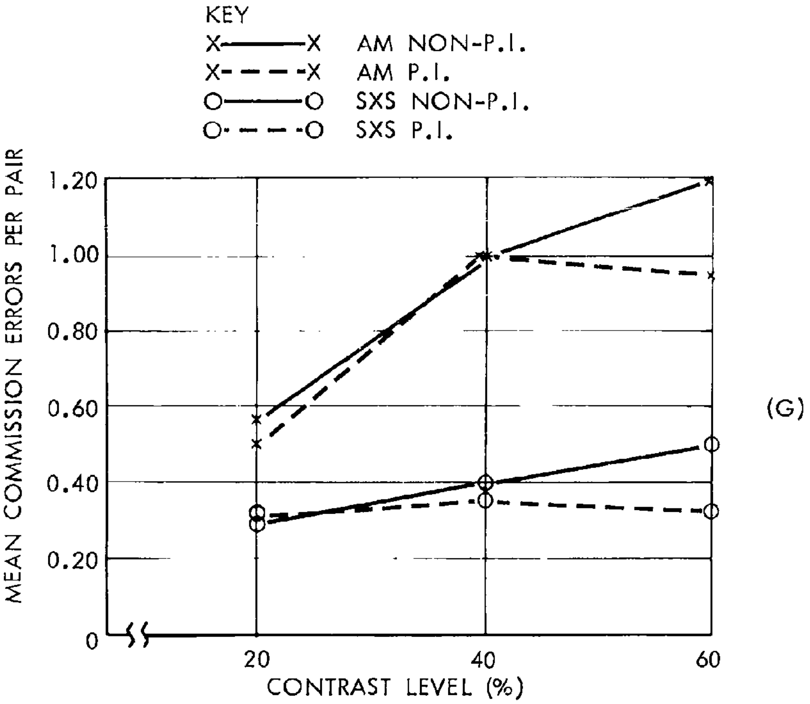


Figure 14 PERFORMANCE AS A FUNCTION OF CONTRAST IN EXPERIMENT I (CONT)

size, or position). In order to be credited with a correct identification, a subject must have accurately reported both pieces of information. The analysis of variance based on identification scores is summarized in Table VIII(B). The analysis shows:

1) As was true for the number of detections, the use of the apparent-motion display system significantly enhanced (p less than 0.01) target-change identification performance. Only 13.7 percent of the target changes were correctly identified when the comparative pairs were displayed side-by-side, whereas 31.0 percent of the changes were correctly identified with the apparent-motion display.

2) No significant difference exists between the two subject samples (non-photointerpreters and photointerpreters) in their ability to accurately identify the type of change and the changed object.

3) The percentage of target changes correctly identified increased significantly (p less than 0.01) with the contrast level of the imagery. The mean percentages of correctly identified target changes were 9.5, 24.5, and 33.4 for the 20-, 40-, and 60-percent contrast levels, respectively.

4) The significant interaction (p less than 0.01) of display method with contrast level can be seen in Figure 14(B) and might be attributable to the greater sensitivity of the apparent-motion display to changes in image contrast over that observed with the side-by-side display.

Because the identification of a change cannot be made without the change first being detected, the similarity in the detection and identification performance differences for the various treatments is understandable. A Pearson product-moment correlation computed between the number of detections and identifications for the observers in each group yielded coefficients of 0.87 for non-photointerpreters and 0.98 for the photointerpreters.

A second identification score, representing the proportion of correctly detected changes that were also correctly identified, was computed (number of correct identifications divided by number of correct detections) for each subject. A summary table of the mean identification scores thus derived is presented in Table VII(C). These data are illustrated graphically in Figure 14(C).

Referring to Table VII(C), it can be seen that photointerpreters successfully identified approximately 16 percent more detected changes than did non-photointerpreters (86.2 percent correct identifications by the former and 70.0 percent identifications by the latter). Furthermore, the proportion of detected changes identified increased as the contrast of the imagery improved (71.5, 79.3, and 83.5 percent with contrast material of 20, 40, and 60 percent, respectively). No indication appeared that identification performance was dependent on the particular display system; 77.4 percent of the detections were correctly identified with the side-by-side display and 78.8 percent were identified with the apparent-motion presentation.

The amount of time required to search for and report the location of each area of change is referred to as detection time. The mean detection time for the various experimental conditions is found in Table VII(D) and is graphically presented in Figure 14(D).

The analysis of variance for detection time is summarized in Table VIII(C). The main effects include:

1) A significantly shorter (p less than 0.01) mean detection time for material viewed in apparent motion (141.7 seconds per pair) than that required with the side-by-side display (197.7 seconds per pair). This difference of almost 1 minute (56 seconds) per comparison represents a time saving of approximately 28 percent by using the apparent-motion display system.

2) No significant differences in the average detection time recorded for nonphotointerpreters (174.3 seconds per comparative pair) and photointerpreters (165.2 seconds per pair).

3) The average time spent in detecting changes did not vary significantly as a function of the contrast level of the imagery. Mean detection times for the 20-, 40-, and 60-percent contrast levels were 161.0, 181.1, and 168.1 seconds, respectively.

The amount of time required to inspect the specific objects within an area of detected change and to reach a decision about which object has changed and in what way it has changed (i.e., size, position, or number) is called identification time. Although a substantial amount of the identification task undoubtedly was completed simultaneously with the reporting of the detection, the relative differences in time scores achieved under the various treatments should still reflect the influence of the independent variables on this aspect of the task.

Identification-time data are summarized in Table VII(E) and presented graphically in Figure 14(E). The results of the analysis of variance are summarized in Table VIII(D). The major findings include:

1) Identification time was essentially the same for both display systems (9.3 seconds with apparent motion and 8.4 seconds for side-by-side display).

2) Photointerpreters required a significantly longer time (p less than 0.05) for each identification (10.4 seconds per identification) than did the nonphotointerpreters (7.4 seconds per identification). Although this difference of 3 seconds per identification is small in absolute magnitude, it does represent a rate differential of approximately 33 percent. It may be due to a tendency for the experienced group to report more detail than was requested of them.

3) The differences in average time required for identifications did not reach statistical significance with the three contrast levels investigated. The mean inspection times were 7.9, 8.9, and 9.8 seconds for the 20-, 40-, and 60-percent contrast levels, respectively.

Total inspection time is a composite of detection time, identification time, response time, interexposure interval, and search time following the last reported identification until signalling completion for each scene.

The average inspection time per comparative pair as a function of the display methods and contrast levels for each group is presented in Table VII(F) and graphically illustrated in Figure 14(F). The results of the analysis of variance are summarized in Table VIII(E). The analysis shows that:

1) Total inspection times were significantly longer (p less than 0.01) for material presented in side-by-side format (205.0 seconds average per pair) than for material seen in apparent motion (160.3 seconds average per pair).

2) No significant differences were revealed as a function of the experience level of the observer. Photointerpreters averaged 178.9 seconds per pair, while non-photointerpreters averaged about 7.5 seconds longer per pair with a mean inspection time of 186.4 seconds.

3) No significant differences in inspection time were revealed as a function of the contrast level of the photography. Mean inspection times of 169.2, 194.6, and 184.1 seconds were obtained for the 20-, 40-, and 60-percent contrast levels, respectively.

Reports of target changes where no change was present are commission errors. The average number of commission errors per comparative pair for each group is reported in Table VII(G) (arranged by treatments and contrast levels) and presented graphically in Figure 14(G). The analysis of variance based on the number of commission errors is summarized in Table VIII(F). The major findings are:

1) The photointerpreter group was not differentiated from the non-photointerpreter group on the basis of the number of commission errors reported. The latter group committed an average of 0.66 errors per pair, whereas the former group averaged 0.57 errors per pair.

2) A significantly larger number (p less than 0.01) of commission errors were made when the material was displayed in apparent motion (0.87 errors per pair) as compared with the number committed with the side-by-side presentation (0.36 per pair). In other words, almost two and a half times as many commission errors were made with the apparent-motion display as with the side-by-side display.

3) The rate at which commission errors are made is significantly related (p less than 0.01) to the contrast level of the imagery. The average number of commission errors per pair per person was 0.42, 0.68, and 0.74 for the 20-, 40-, and 60-percent contrasts, respectively.

Applying Duncan s new multiple range test to the performance differences between contrast conditions reveals that only at the 20-percent contrast level is performance significantly different from that exhibited at either of the other levels.

4) No significant interaction existed between display method and contrast level.

An equal number of target changes of each type (size, number, and position) were introduced in a controlled, systematic fashion. An evaluation of the relative frequency with which each type of change was detected is summarized in Table IX.

Table IX PERCENT CORRECT DETECTIONS FOR EACH OF THREE CLASSES OF CHANGE

		CHANGE IN NUMBER	CHANGE IN SIZE	CHANGE IN POSITION
Non- P.I. Group	AM	28.7	34.3	31.5
	S S	14.8	15.7	8.3
P.I. Group	AM	27.8	37.0	27.8
	S S	17.5	16.7	9.3
MEANS		22.2	25.9	19.2

From Table IX, it can be seen that, averaging across groups and display methods, the changes most difficult to detect were changes in position (19.2 percent) and changes in size were the most easily detected (25.9 percent) with changes in number being of intermediate difficulty (22.2 percent).

Duncan's new multiple range test was applied to test for performance differences and failed to reveal a statistically significant difference between any pair of mean values.

The mean inspection times associated with the comparative pairs containing each of the three types of change are summarized in Table X.

Table X MEAN INSPECTION TIME PER COMPARATIVE PAIR (SECONDS) Each Of The Three Classes Of Change

		CHANGE IN NUMBER	CHANGE IN SIZE	CHANGE IN POSITION
Non-P.I. Group	AM	157	168	189
	S S	196	203	217
P.I. Group	AM	141	154	163
	S S	212	187	214
MEANS		177	178	196

Although apparently longer average inspection times were recorded for those photographs containing changes in position (196 seconds) than those obtained for photographs with changes in size (178 seconds) or number (177 seconds), Duncan's new multiple range test did not reveal these differences to be statistically significant.

CONCLUSIONS

The major purpose of this experiment has been to determine the influence of display method, interpreter experience, and image contrast on the speed, accuracy, and completeness of target-change detection and identification from comparative-cover aerial photography.

Summarizing briefly the main findings relative to each of the experimental variables, it has been shown that:

1) Significantly more changes were detected in significantly less time in the apparent-motion display than in the side-by-side display. A significantly larger percentage of the target changes were correctly identified with the apparent-motion display, although this difference was not evident for identifications considered in proportion to detections of targets correctly detected, approximately an equal proportion was identified with each display system. Identification time did not vary as a function of the display method, but a significantly larger number of commission errors were made with the apparent-motion format.

2) The two subject samples, dichotomized on the basis of their experience with aerial photography, were differentiated only in the amount of time required to make an identification of the change: photointerpreters required significantly longer identification times than non-photointerpreters.

3) Reducing the contrast of the imagery results in a significant reduction in the number of changes detected and the number of changes identified. The apparent-motion display system proved more sensitive to changes in image contrast and improved significantly with each increase in contrast level, whereas performance with the side-by-side display did not improve for contrasts above 40 percent. Neither detection nor identification time was dependent on the contrast level of the imagery. Commission errors were significantly higher with higher-contrast imagery.

Consideration must be given to the specific characteristics and limitations of the stimulus material, subject samples, measurement techniques, and administration procedures in extrapolating the present data or generalizing to situations deviating from the experimental conditions. Perhaps the most restrictive element in the present study is the nature of the stimulus material employed. The two photographs comprising each comparative pair consisted of successive pictures obtained during a single pass over a target area. This provided comparative imagery essentially devoid of many forms of "visual noise" (such as would result from differences in sun angle, atmospheric conditions or seasonal ground cover) typically present in operationally obtained comparative cover photography.

Although all ground objects appeared to be moving when viewed in the apparent-motion display due to the disparity in the nadir points on each photograph, the movements were essentially unidirectional except for those objects that constituted target changes. Thus, the task confronting the observer in this situation required a discrimination between different types, amounts, and directions of perceived motion. Although not optimal for the apparent-motion technique, materials requiring the discrimination of irregularities in a relatively uniformly changing field would appear to be favorable to this display method.

Another consideration relating to the test photography used in this study is that the only target changes represented in the comparative pairs were those introduced by the artist. In this respect, all changes could be classified as "artificial." The artificiality of the objects added, removed, or modified was not discernible even to critical experts specifically instructed to search for such art work. This degree of realism is attributable to the skill and experience of the artist who made the changes on enlarged prints and the diminution of differences in texture and definition with successive reproductions of the photographs. The procedure of introducing target changes is highly desirable because it permits the establishment of absolute ground truth for the accurate evaluation of the completeness of information extraction.

Caution should be exercised in applying the present results to predictions of performance by currently practicing military photointerpreters. Photointerpreters who participated in this experiment varied widely in the amount and type of training and experience with aerial photography; also, none were currently engaged in full-time pursuit of this activity. They should be considered as occupying some intermediate position along the continuum between non-photointerpreters and currently active photointerpreters.

Although, in this experiment, non-photointerpreters did as well as the photointerpreters in the detection of change with either display method, the photointerpreters appeared to do better in the identification of the detected changes, particularly with degraded imagery. That the photointerpreters required more time to make each identification was apparent in the records of the verbal identification responses from each subject. They consistently responded with descriptions containing more information than that required for the simple identification.

An attempt was made in this investigation to obtain discrete quantitative measures of the time required to make each detection and the time required to identify the change. The measure of detection time, from activation of the shutter exposing the photographs to depressing the key corresponding to the area of change, is relatively straightforward. The identification time, on the other hand, should not be interpreted as absolute because a certain amount of the identification process was obviously completed during the detection portion of the task. This is particularly true in view of the "low level" interpretation (identifying the type of change and naming the object) required in this study. Both measures, however, are considered sufficiently sensitive to reflect significant effects of the independent variables.

The results of this experiment indicate that the apparent-motion display technique: (1) is superior to the side-by-side presentation for the detection of changes (both in completeness and time), (2) is comparable to the side-by-side display in identification of the changes detected and identification time, and (3) is inferior to the side-by-side format in the number of commission errors elicited. It is highly probable that the advantages of the apparent-motion display can be further enhanced and the limitations diminished by making certain improvements in the display apparatus. Such changes might include the modification of the equipment to facilitate alignment of the two photographs and to permit observer control over the alternation rate of the two images because it appears that the optimal alternation rate for detection may not be optimal for the identification task. It is recommended that continued research and development of the apparent motion display system be conducted to further improve the extraction of information from aerial photography.

EXPERIMENT II

INTRODUCTION

Experiment II was designed to investigate change-detection performance of photointerpreters and non-photointerpreters, using both the side-by-side and apparent-motion displays, as a function of various levels of scale, complexity, and quality of the imagery being inspected. Aerial photography representing three scale ratios (1:10,000, 1:20,000 and 1:40,000) and three scene complexities (rural, suburban, and industrial-military) were reproduced with three imposed degradation levels and presented to a group of non-photointerpreters using two display methods. The lowest and highest quality imagery at scales 1:10,000 and 1:40,000 were subsequently presented to photointerpreters for inspection using both display methods. Performance evaluation included both the relative accuracy of change detection and the speed with which the task was accomplished.

SUBJECTS

Eighteen Boeing employees served as the subject sample of non-photointerpreters. Qualifications for inclusion in this sample were: (1) "normal" (corrected to 20/20) vision, (2) no formal training or experience in photointerpretation, and (3) that they had not participated in Experiment I. Their current job assignments with The Boeing Company were predominantly as shop technicians, laboratory technicians, and junior and senior research scientists in the Bioastronautics organization.

The photointerpreters for the experiment consists of eight persons from within The Boeing Company who had previously had formal training or experience in either military or civilian photointerpretation. A summary of their backgrounds in photointerpretation can be found in Appendix I. Five of these subjects had also served as observers in Experiment I.

APPARATUS

The side-by-side and apparent-motion display system and the push-button-matrix response system was the same as that described for Experiment I. All optical components were cleaned and realigned, and the light sources were replaced and calibrated before the beginning of data collection.

STIMULUS MATERIAL

With the assistance of the Aeronautical Charting and Information Center (Detachment I) in Washington, D.C., 566 9-inch by 9-inch aerial photographs were selected from the Air Force records of comparative coverages of the U.S. Zone of the Interior that were currently available from the Air Force, the Department of the Interior, or the Department of Agriculture. These photographs represented 53 separate missions flown over 17 different target areas. A descriptive inventory of the material received is included in Appendix III.

Upon receipt of the positive prints, temporary mosaics were constructed for the purpose of evaluating print quality, appropriateness of ground activity, and correspondence of flight tracks and image scale. Subsequent to this review, an order was submitted to Aeronautical Charting and Information Center for 522 positive transparent prints that included 61 deletions from and 17 additions to the original order. The center was able to comply with this request except for coverage held by the Department of Agriculture. Since this collection agency was in the process of relocating its photo library, it could not make available either transparent prints or the negatives of the desired coverages. Therefore, Boeing made negatives directly from the original prints. In this way, it was possible to make the final selection of the required 72 comparative pairs (eight samples from each of three backgrounds — rural, suburban, and industrial-military — at the three desired scales — 1:10,000, 1:20,000, and 1:40,000) from within 47 separate mission coverages.

After these original 9-inch by 9-inch photographs that contained desired target areas had been selected, negatives were made from the transparencies (except in the case of the Department of Agriculture coverages where negatives were made from the positive prints), and enlargements to a 20-inch by 20-inch format were prepared. The desired target areas within each of the 144 photographs (72 comparative pairs) were then delineated by crop marks and a scale-reference line added. Target changes were then introduced on one member of each picture pair (with a few exceptions where no changes were introduced) by a skilled artist. These changes were modeled after changes observed elsewhere in the photograph and were included here in an attempt to establish the validity of this procedure for introducing targets on imagery where no "real" targets exist or where ground truth cannot be determined. Thirty-five such targets, matched in size and contrast with existing "real" targets, were added (nine in the 1:10,000, 14 in the 1:20,000, and 12 in the 1:40,000 scale photographs) with the number per comparative pair varying between zero and three.

The final negatives of the cropped target areas were then prepared. The scale-reference lines were also included in the periphery since these would be required in producing the final 4-inch by 4-inch transparencies at the desired scales.

Of the numerous techniques used to degrade photographic quality, defocusing is probably most often reported in the literature since it is perhaps the easiest and most readily available means of creating a blurred image. A number of research persons, such as Stanley Ballard, W.E.K. Middleton, and Glen A. Fry (Fry, 1957), have discussed the limitations of this technique. The major limitation is that defocusing does not lend itself to quantitative specification. The method used in this experimental investigation is one recommended by Fry (1957) that lends itself to qualitative description and quantification.

A neutral-density filter was produced according to the procedure advanced by Fry and as described in detail in Appendix IV. The central density was 0.48 with the gradient along any diameter an approximation of the gaussian distribution. The deviation was in the platykurtic direction, and the 4.0 standard deviation point on this curve was equated to the entrance pupil of an Eastman EKtanon (10-inch focal length) lens. The enlarging lens and filter were mounted in an 8-inch by 10-inch Elwood enlarger. The lens, filter, and optical path were checked and adjusted to give a homogeneous blur in both X and Y directions through the range of blur planned for this study.

The 4-inch by 4-inch negatives were used in the Elwood enlarger to make the two levels of blur. The procedure was to preset the enlarger at -2.0 millimeters, and later -4.0 millimeters, from best focus and then match the image size to that of the original negative. The gaussian filter was placed over the entrance pupil, and all prints were made without changing the enlarger. Calibration of the condition was made by printing a resolution chart on the same transparency material (Type 3 Kodalith) and developing it in Dektol 1:1. (The calibration target was the USAF resolution chart, developed under Contract Number 680-66-SA-10 by the Buckbee-Mears Company, St. Paul, Minnesota.) This print and those for all other image degradation conditions were examined with a Model 4 Ansco microdensitometer. The resulting conditions are summarized in Table XI and Figure 15. The blur levels were selected to produce a maximum practical range (without false resolution) on the basis of appearance.

Table XI PHYSICAL INFORMATION RELATIVE TO BLUR CONDITIONS
Experiment II Stimulus Materials

MEASURE	IMAGE QUALITIES		
	HIGHEST QUALITY	INTERMEDIATE QUALITY	POOR QUALITY
Edge Gradient (Minimum Density to Maximum Density)	0.31 mm	0.65 mm	1.25 mm
Resolution (Lines Per mm)	64.0	1.25	0.80
Resolution (Ground Resolution in Feet)			
1:10,000 Scale	0.505	26.2	41.0
1:20,000 Scale	1.010	52.4	82.0
1:40,000 Scale	2.020	104.8	164.0
Acutance $GD/(X_B-X_A)$	0.0255	0.0154	0.0008
Density Range	1.2	1.2	1.2

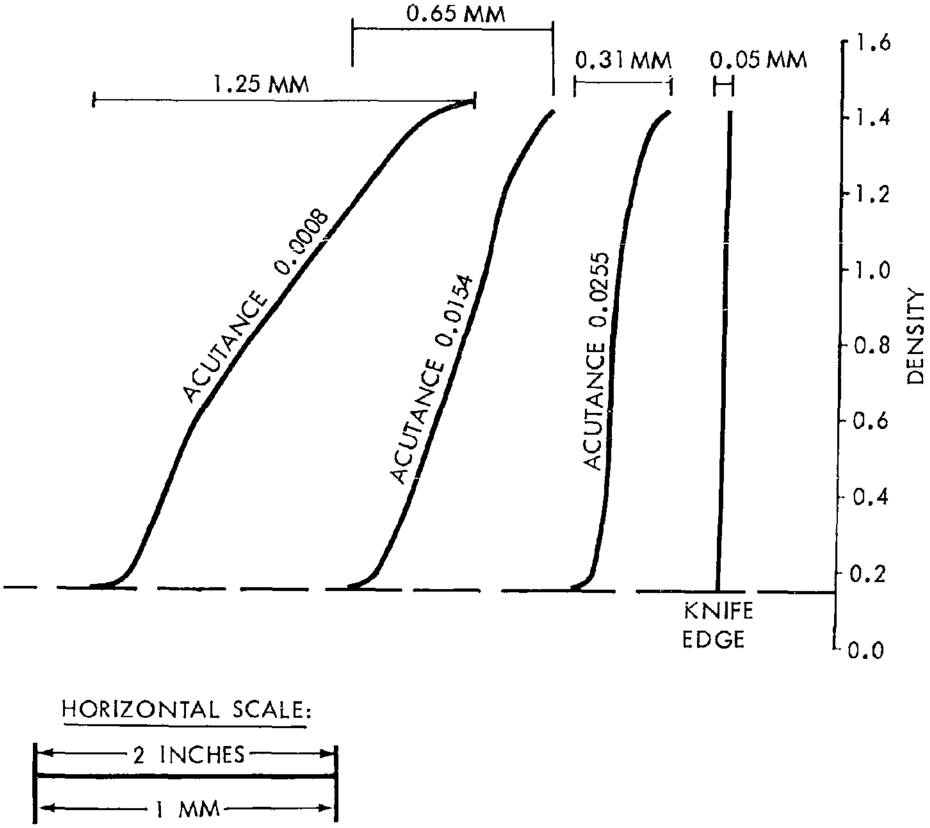


Figure 15 MICRODENSITOMETER TRACINGS OF EDGE GRADIENTS FOR A KNIFE EDGE AND THE THREE PHOTOGRAPHIC QUALITIES USED IN EXPERIMENT II
Ansco Model 4 Microdensitometer; 2 By 60-Micron Slit

These physical conditions describe the best conditions that could prevail for each blur level. Each photographic negative had its own physical characteristics and, when printed through the Elwood enlarger with the selected degree of defocus and the gaussian filter, was made poorer by the imposed blur. The resulting image quality could be no better than the values given in Table XI, and to the extent that the original is less than perfect, this quality will be less than the tabulated values. The highest and lowest image qualities for each of the three scales and three complexities are illustrated in Figures 16, 17, and 18.

TRAINING

All 18 subjects constituting the non-photointerpreter population sample were given the training program described for Experiment I. Photointerpreters who had not participated in Experiment I were likewise given the complete training program described for that experiment. For the five photointerpreters who had served as observers in Experiment I, a brief review of the basic operating procedures of the display system and the response panel was provided. They were then presented three of the "high visual noise" training slides under each of the presentation methods to reacquaint them with how aerial photography appears when so displayed and to allow them to remaster the use of the response panel for indicating target locations. Immediate feedback on their performance was provided after each response and again at the completion of each of the three comparative pairs.

INSTRUCTIONS

In addition to the general instructions describing the purpose of the research program, the importance of the contributions being made by the observer, and the performance criteria being used in the evaluation, the following task-specific instructions were given.

> "The task which you are being asked to perform next differs significantly from that which you were asked to do in the training session (and in the preceding Experiment) in one respect. With the preceding material you were required to report the location of each and every change which occurred between the two photographs and also to identify the object which had changed and the type of change which had occurred (whether it was a change in size, number, or position). Since among the photographs you will be viewing next are some representing what we call 'high activity areas' such as New York City and since the elapsed time between the first and the second photograph may be as much as several years, the job of locating and identifying <u>all</u> of the changes in such an area becomes prohibitive within any reasonable demands on your valuable time. To make the task a little more reasonable we will designate a specific target class before presenting each set of pictures and you will be required to locate and report only those changes which have occurred to objects falling within the specified target class. For instance, I may tell you to look only for changes in large,

Figure 16 ILLUSTRATIONS OF HIGH AND LOW IMAGE QUALITIES WITH RURAL TERRAIN 1 : 10,000 Scale

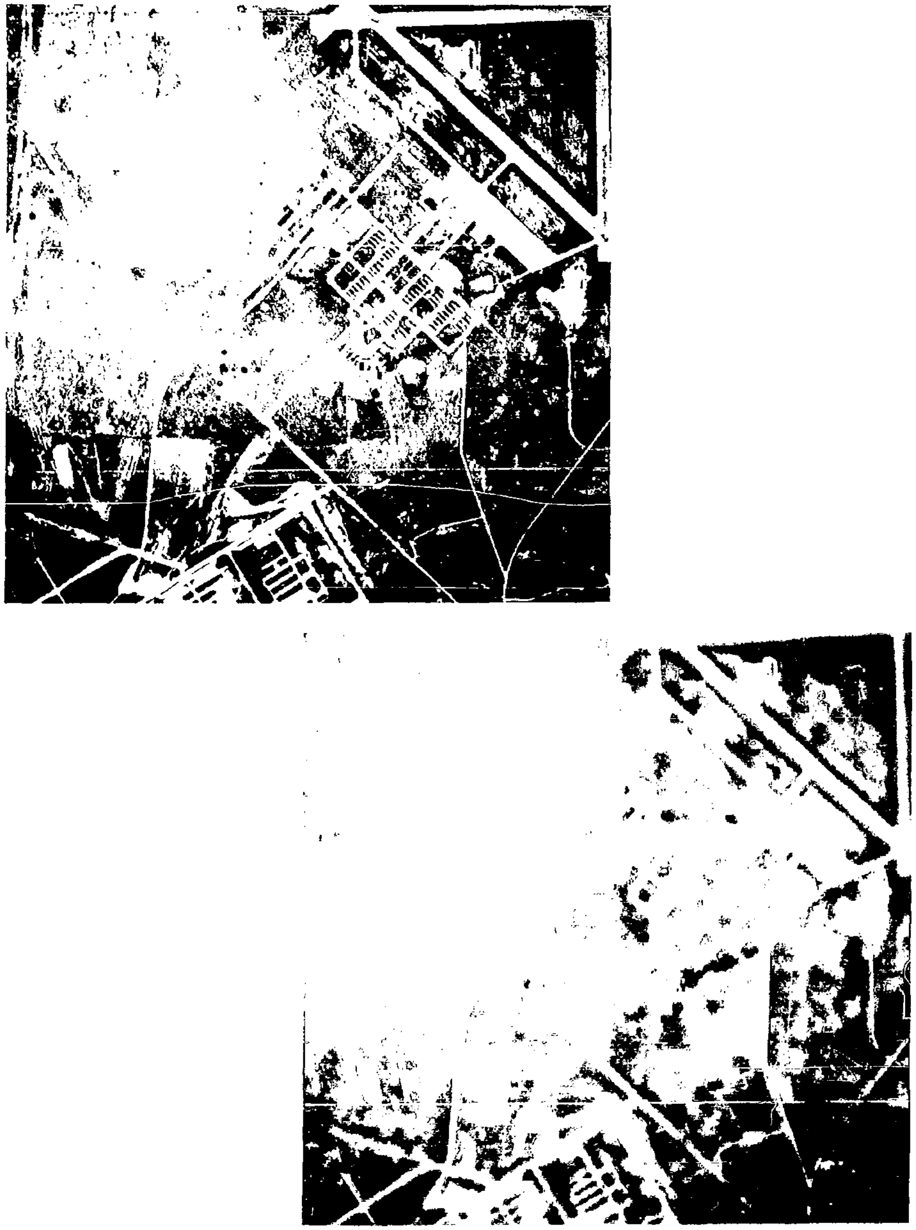


Figure 17 ILLUSTRATIONS OF HIGH AND LOW IMAGE QUALITIES WITH SUBURBAN TERRAIN 1 : 20,000 Scale

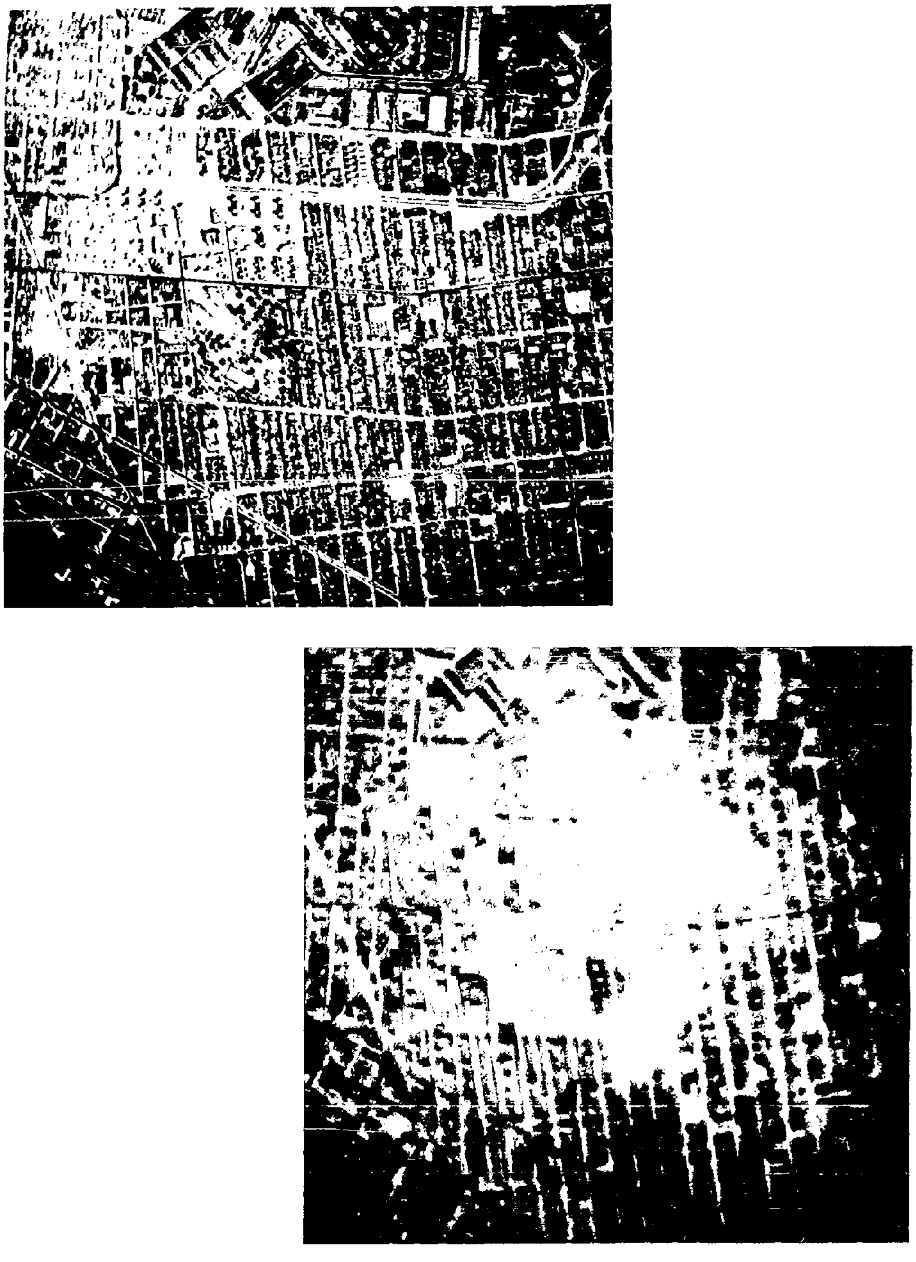


Figure 18 ILLUSTRATION OF HIGH AND LOW IMAGE QUALITY WITH INDUSTRIAL TERRAIN 1 : 40,000 Scale

NON-RESIDENTIAL BUILDINGS, in which case you would not report the addition of new homes in the area but you would report the addition of a new warehouse or factory. Other examples of the types of target classes you may be asked to look for would be ROADS AND HIGHWAYS, DOCK ACTIVITY in a harbor scene, or perhaps ANY MAN-MADE OBJECT in the case of pictures of desolate rural terrain.

"You will still be required to tell us in what way the object you are reporting has changed (that is, whether it is a change in size, position, or number). Your verbal description of the specific object within the designated target class that you have detected as changed will aid us in obtaining an accurate measure of your performance.

"The criteria to be applied in evaluating your performance will be ACCURACY, COMPLETENESS, AND SPEED. Therefore, you should be certain that you have detected all of the changes falling in the target class specified (COMPLETENESS), that you have accurately identified the object changed and how it has changed (ACCURACY), and that you are working as rapidly as possible without sacrificing either accuracy or completeness.

"Are there any questions before we begin?"

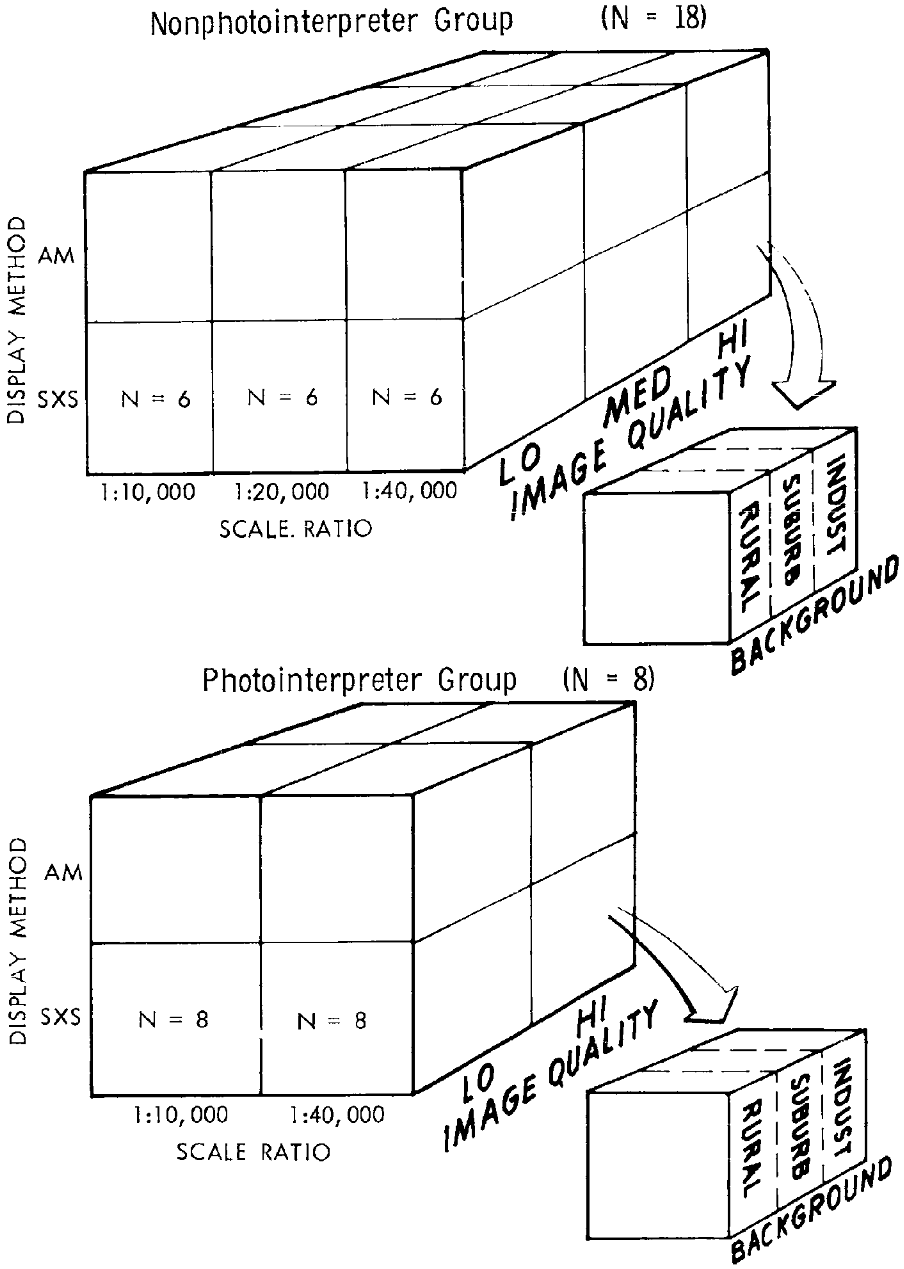
DESIGN

The basic experimental design is represented schematically in Figure 19. Each of the 18 non-photointerpreters was randomly assigned to one of three groups of six subjects each. All members of a given group viewed only the material representing one of the three scales — 1:10,000, 1:20,000, or 1:40,000. Within groups, each subject inspected 18 different comparative pairs; two comparative pairs represented each of the three background complexities reproduced at each of the three levels of image quality. Half were viewed side by side and the other half were viewed in apparent motion.

Counterbalancing for presentation order effects was achieved by arbitrarily designating half of the subjects within each group to be presented half of the imagery in side-by-side format first and then the remaining half of the material in apparent-motion format; the other half of the subjects viewed the material in the reverse display order.

To avoid any systematic biasing of the results due to the order in which the three background complexities were presented, each of six possible permutations of the three background orders were experienced by each observer — one order for each of the blur/display-method (three by two) conditions.

Each of the six subjects within a group was assigned to one of the six possible presentation orders for the three image qualities so that, within each group, a complete Latin square was represented.



Nonphotointerpreter Group (N = 18)

Photointerpreter Group (N = 8)

Figure 19 SCHEMATIC REPRESENTATION OF BASIC DESIGN FOR EXPERIMENT II

The eight photointerpreters each inspected 24 separate comparative pairs. Half were viewed side by side and half with apparent motion. Of the 12 areas seen under either display system, one represented each of the background/scale/image-quality (three by two by two) conditions.

Complete counterbalancing for effects attributable to the presentation order of the two image qualities and the two scales was achieved within subjects. Half of the subjects used the side-by-side display first; the other half used the apparent-motion display first.

RESULTS

Because absolute ground truth for the stimulus material used in this investigation was not available, the following procedure was applied to establish a performance criterion for evaluating the treatment effects:

> All of the responses (indicating the detection of change) made by either group of subjects were itemized and pooled. Added to this list of responses were responses contributed by members of the research team as they prepared and reviewed the comparative pairs. When all subjects had inspected a specific picture pair, each of the responses elicited was evaluated for correctness by reference to the enlarged photographs (20 inches by 20 inches) used in preparing the final transparencies for the final evaluation. Thus, each individual's performance became relative to the total number of changes detected by the composite group, and only those changes detected by at least one of the observers and verified on the enlargements were included in the analysis of completeness. Changes reported but not verified on the enlargements were tabulated as errors of commission. A commission error was also recorded when a subject reported a change that involved an object belonging to some target class other than that which he had been instructed to search for and report.

Significant differences in accuracy as a function of scale were not anticipated because the scoring criterion was derived from the composite group performance at each scale.

Tables XII (A) and (B) summarize the percentage of correct detections, mean inspection time per comparative pair, and the mean number of commission errors per pair for each of the treatments and treatment levels. These data are presented graphically in Figures 20 through 26.

The nature of the stimulus material available for this experiment required that the search be limited to certain specifically designated target classes. Because, in some instances, only a single type of target was assigned, the identification report could not be distinguished from detection. Furthermore, the type of change occurring between the two photographs of any pair predominantly concerned changes in number (additions or deletions), and only rarely were changes in size or position included. These factors, coupled with the high correlation found in Experiment I between detections and identifications (r = 0.94 for combined groups), seemed to justify the exclusion of identification data from further analysis.

Looking first at the data obtained from non-photointerpreters, the following results were obtained:

1) The percentage of targets correctly detected was essentially the same (53.1 percent as compared with 47.7 percent) for both display methods.

Table XII PERFORMANCE MEANS FOR ALL CONDITIONS OF EXPERIMENT II

(A) Non-P.I.

	DISPLAY METHOD	IMAGE QUALITY	PHOTO SCALE	SCENE BACKGROUND
% Correct Detections	AM = 53.1 SS = 47.7	Hi = 59.6 Md = 56.4 Lo = 41.3	10K = 57.7 20K = 64.8 40K = 28.8	Rur. = 53.1 Sub. = 46.9 Ind. = 51.3
Mean Time Per Pair (Seconds)	AM = 142.5 SS = 167.1	Hi = 159.7 Md = 154.4 Lo = 150.4	10K = 117.9 20K = 163.0 40K = 183.6	Rur. = 138.1 Sub. = 151.4 Ind. = 175.0
Commission Errors Per Pair	AM = 1.68 SS = 1.51	Hi = 1.66 Md = 1.44 Lo = 1.68	10K = 1.06 20K = 2.07 40K = 1.64	Rur. = 1.56 Sub. = 1.52 Ind. = 1.70

10K = 1:10,000

(B) P.I.

	DISPLAY METHOD	IMAGE QUALITY	PHOTO SCALE	SCENE BACKGROUND
% Correct Detections	AM = 50.3 SS = 42.1	Hi = 58.5 Lo = 33.9	10K = 50.0 40K = 42.5	Rur. = 46.5 Sub. = 43.6 Ind. = 48.6
Mean Time Per Pair (Seconds)	AM = 128.1 SS = 159.6	Hi = 145.0 Lo = 142.7	10K = 120.9 40K = 166.7	Rur. = 124.5 Sub. = 158.9 Ind. = 148.1
Commission Errors Per Pair	AM = 0.93 SS = 1.18	Hi = 1.01 Lo = 1.09	10K = 0.81 40K = 1.29	Rur. = 0.91 Sub. = 1.19 Ind. = 1.06

Table XIII ANALYSIS OF VARIANCE

Summary Table For Non-P.I.

		TIME		PERCENT DETECTION		COMMISSION ERROR	
SOURCE	df	ms	F	ms	F	ms	F
Between Subject Total	(17)						
Scale (S)	2	121932	2.96	39832	12.38**	27.5	1.328
Between Subject Error	15	41070		3217		20.7	
Within Subject Total	(306)						
Methods (M)	1	48891	12.4**	2467	2.433	2	
Blurs (B)	2	2326		8862	8.74**	2	
Backgrounds (BG)	2	37686	9.6**	1075	1.06	1	
M x S	2	966		32		4.5	1.541
M x B	2	585		99		1.33	
M x BG	2	1804		837		2	
B x S	4	166		632		.5	
B x BG	4	1957		1502	1.48	2	
S x BG	4	11639	2.9*	1091	1.076	3.25	1.113
M x S x B	4	992		805		1.25	
M x B x BG	4	1881		455		2	
S x B x BG	8	3497		515		2.75	
M x S x BG	4	1059		1121	1.106	.5	
M x S x B x BG	8	1329		882		3.5	1.198
Within Subject Error	255	3927		1014		2.92	
TOTAL		323					

* 0.05
** 0.01

Table XIV ANALYSIS OF VARIANCE
Summary Table For P.I.

		TIME		PERCENT DETECTION		COMMISSION ERROR	
SOURCE	df	ms	F	ms	F	ms	F
Scale (S)	1	100650	13.35**	2730	2.35	11	5.0*
Blur (B)	1	261		29107	25.01**	-	
Background (BG)	2	19754	2.62	399		1	
Method (M)	1	47754	6.33*	3251	2.79	3	
S x B	1	93		1102		-	
S x BG	2	9701	1.29	347		6	2.7
S x M	1	8775	1.16	1441	1.24	3	1.4
B x BG	2	1299		161		1	
B x M	1	275		390		-	
M x BG	2	13		286		-	
S x B x BG	2	4091		285		1	
S x B x M	1	5		205		-	
S x M x BG	2	515		647		.5	
B x M x BG	2	1678		1200	1.03	.5	
S x M x B x BG	2	3294		111		-	
Within Cells Error	168	7539		1164		2.2	
TOTAL	191						

* 0.05
** 0.01

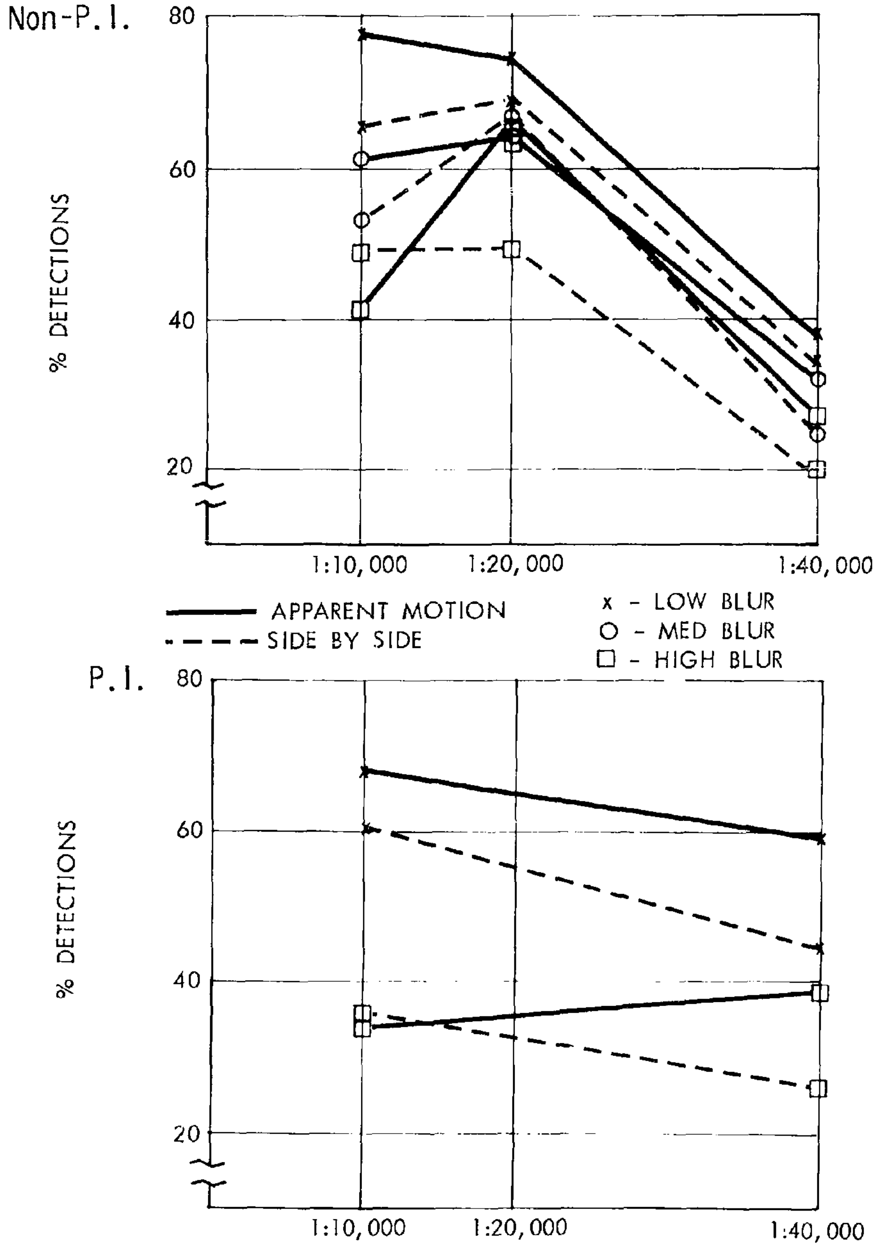


Figure 20 PERCENT CORRECT DETECTION AS A FUNCTION OF SCALE IN EXPERIMENT II

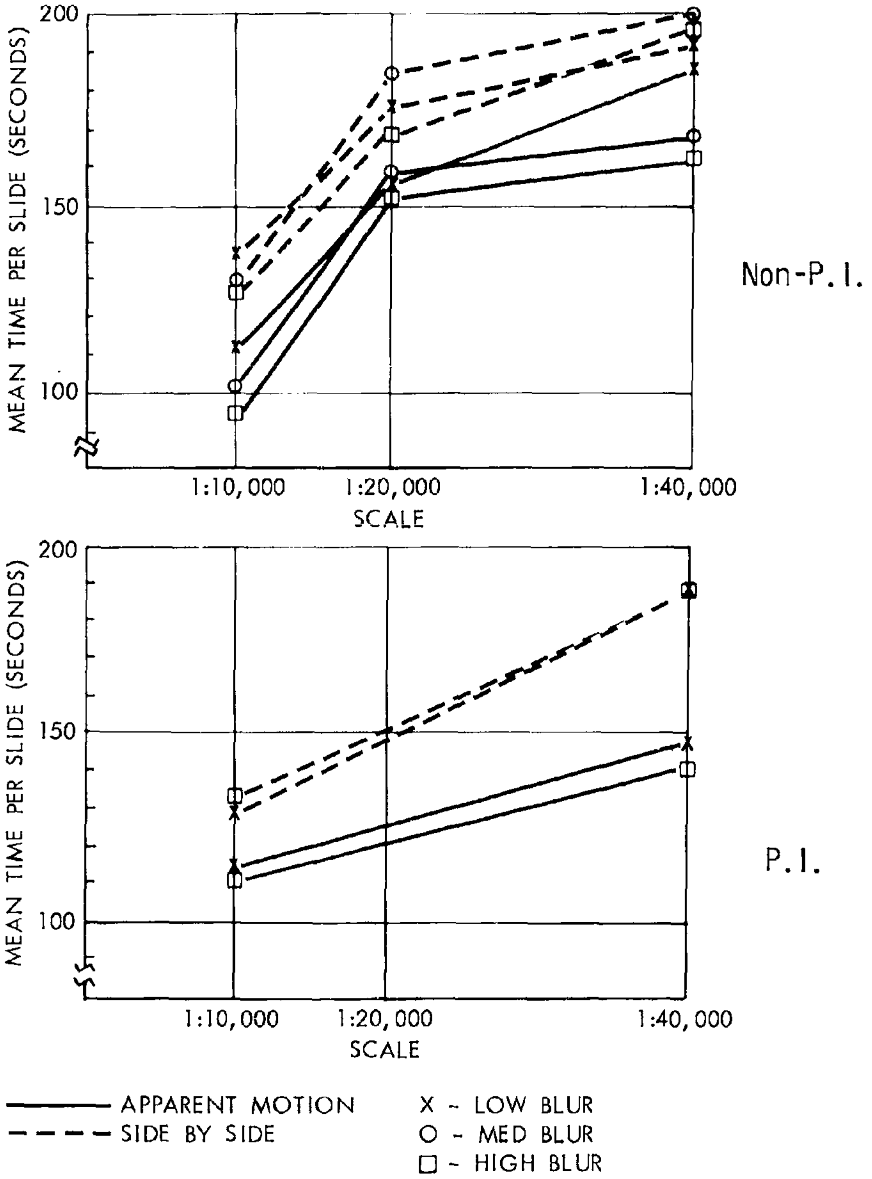


Figure 21 MEAN TIME PER COMPARATIVE PAIR FROM NON-P.I. AND P.I. OBSERVERS AS A FUNCTION OF SCALE, IMAGE QUALITY, AND DISPLAY METHOD

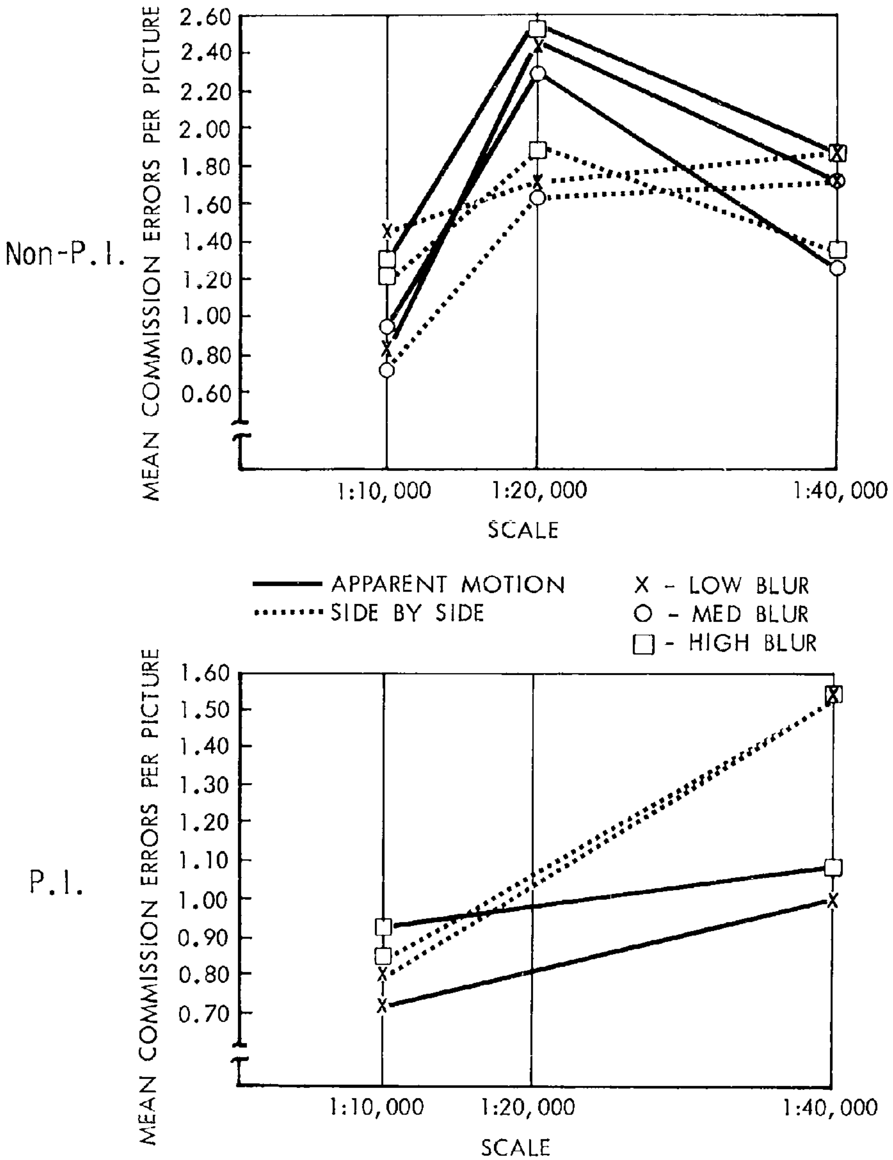


Figure 22 MEAN NUMBER OF COMMISSION ERRORS PER COMPARATIVE PAIR FROM NON-P.I. AND P.I. OBSERVERS AS A FUNCTION OF SCALE, IMAGE QUALITY, AND DISPLAY METHOD

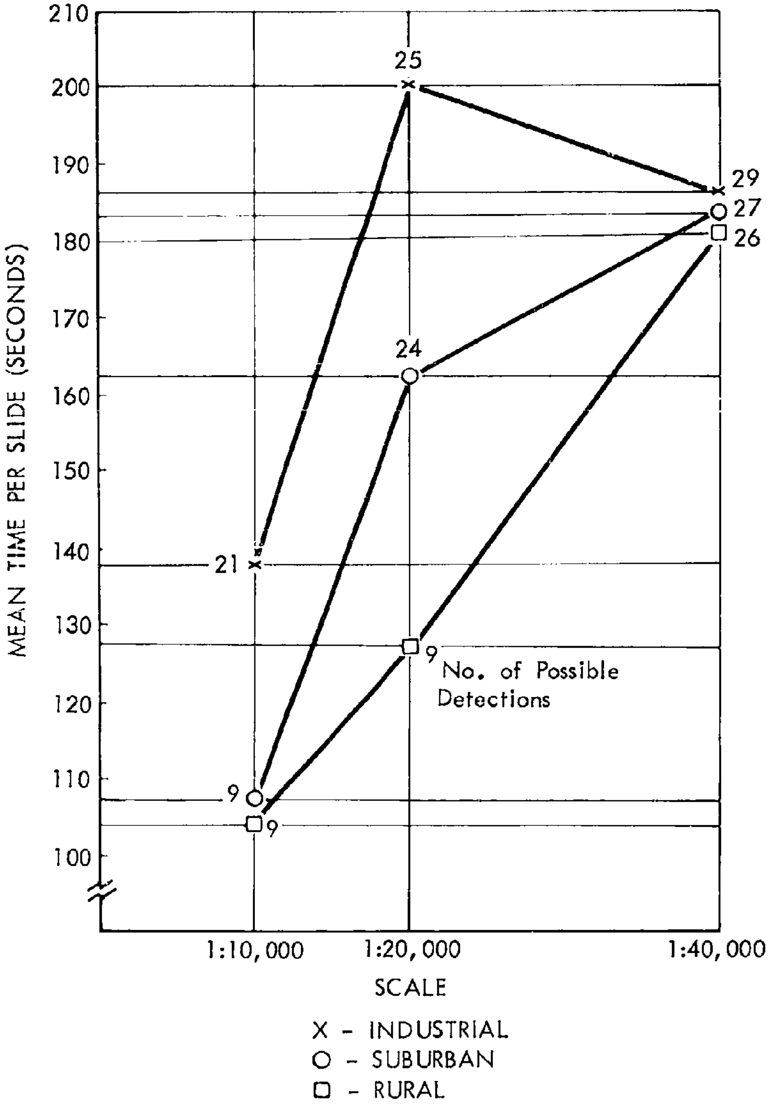


Figure 23 MEAN TIME PER COMPARATIVE PAIR AS A FUNCTION OF SCALE FOR THREE TERRAIN COMPLEXITIES, NON-P.I.

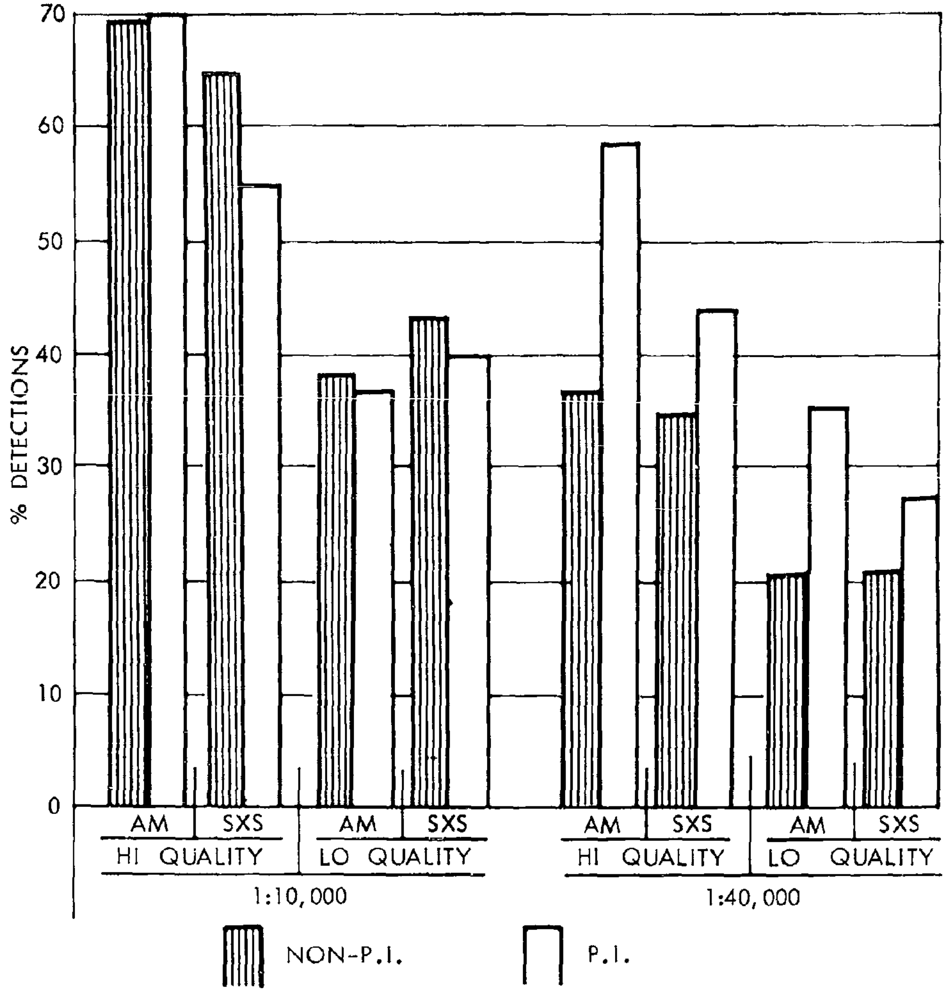


Figure 24 BAR GRAPH OF MEAN
PERCENT DETECTIONS AS A FUNCTION OF DISPLAY METHOD,
SCALE AND IMAGE QUALITY Non-P.I. And P.I.

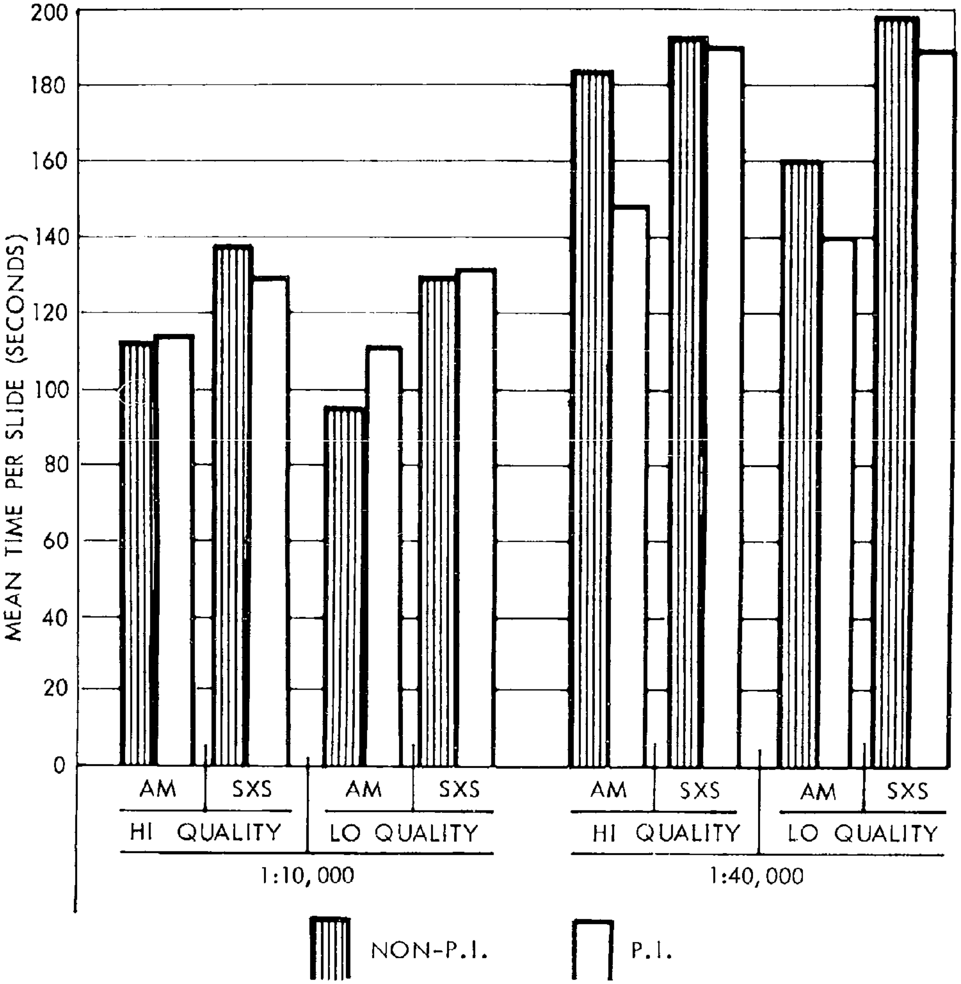


Figure 25 BAR GRAPH OF
DETECTION TIME AS A FUNCTION OF DISPLAY
METHOD, SCALE, AND IMAGE QUALITY Non-P.I. And P.I.

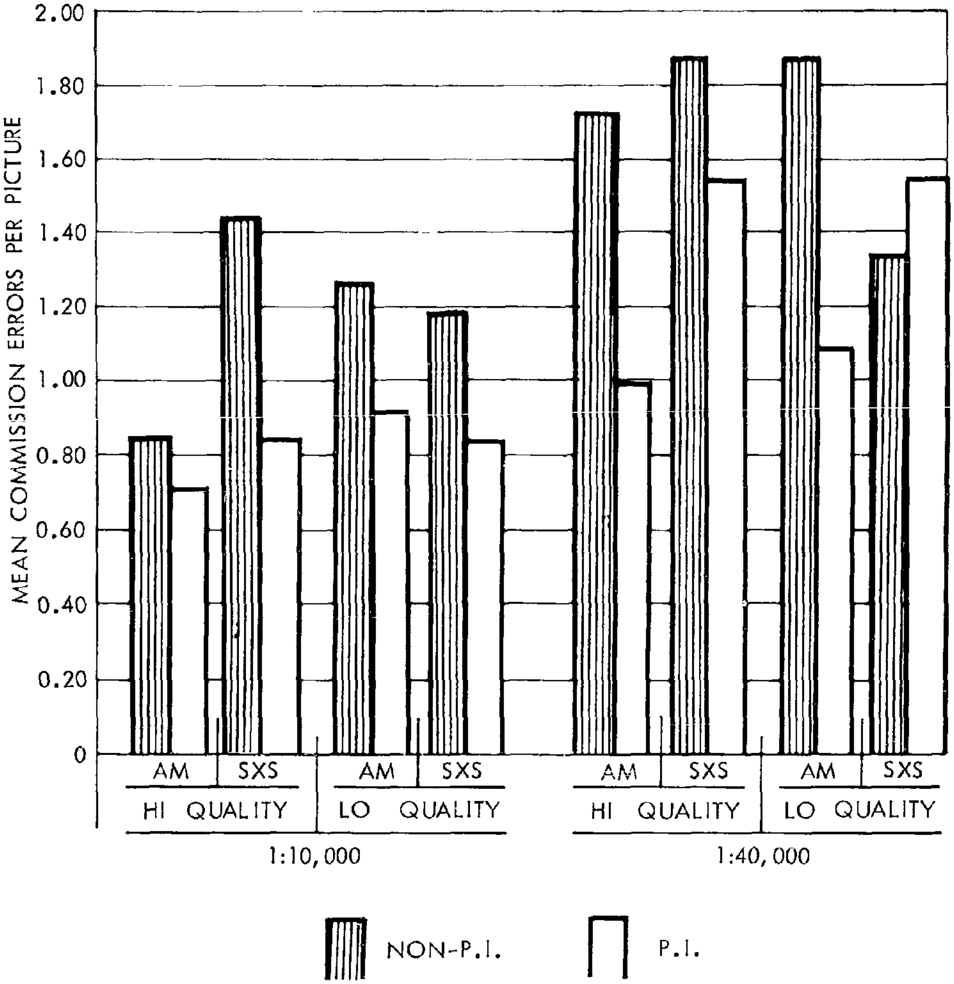


Figure 26 BAR GRAPH OF
COMMISSION ERRORS AS A FUNCTION OF DISPLAY METHOD,
SCALE, AND IMAGE QUALITY Non-P.I. And P.I.

The difference of 5.4 percent favoring the apparent-motion display was not significant (see Table XIII).

2) The percentage of targets correctly detected was significantly related (p less than 0.01) to the quality of the imagery being viewed (see Table XIII). Application of Duncan's new multiple range test (Edwards, 1950) shows that the performance levels achieved at each level of image quality (59.6, 50.4, and 41.3 percent for the high, medium, and low qualities, respectively) is significantly different (p less than 0.01) from that at each of the other levels.

3) The percentage of targets correctly detected did not vary systematically with the scale of the imagery (57.7 percent at 1:10,000, 64.8 percent at 1:20,000, and 28.8 percent at 1:40,000). The difference between the performance level exhibited with the 1:40,000 imagery and that attained with the 1:10,000 and 1:20,000 material was considerable (28.9 and 36.0 percent, respectively), and was significant at the 0.01 level of confidence (see Table XIII).

4) The percentage of targets correctly detected was not related to the complexity of the background contained in the photographs. For rural material, 53.1 percent of the targets were detected; for suburban material, 46.9 percent; and for the high-complexity industrial background, 51.2 percent.

5) The non-photointerpreters required significantly less time to inspect each pair of photographs when presented in apparent motion than they did when the photos were displayed side by side (p less than 0.01, see Table XIII). An average of 167.1 seconds was required to search each pair in the side-by-side format; an average of only 142.5 seconds was required for the task with the apparent-motion display — a saving of about 25 seconds per comparison, or about 15 percent.

6) The amount of time required to search each comparative pair did not change significantly as the quality of the imagery was varied (see Table XIII). Mean inspection times of 159.7, 154.4, and 150.4 seconds were recorded for the high-, medium-, and low-quality imagery, respectively. If the small but systematic differences are indicative of a trend, it would suggest that non-photointerpreters spend more time on the task as image quality improves.

7) Although there is a strong indication that mean inspection time increases as the scale of the photography becomes smaller (117.9 seconds with 1:10,000-scale photographs, 163.0 seconds with 1:20,000-scale photographs, and 183.6 seconds with 1:40,000-scale photographs), the variance within and between groups was sufficient to make it impossible to reject the null hypothesis with acceptable confidence (see Table XIII).

8) The analysis reveals a significant time difference (p less than 0.01) associated with the background complexity (rural, suburban, or industrial) contained in the imagery (see Table XIII). Application of Duncan's new

multiple range test to the differences between backgrounds reveals that the mean time required to inspect rural and suburban photographs (138 and 151 seconds, respectively) did not differ significantly from each other. The average of 175 seconds required to search the industrial scenes was significantly longer (p less than 0.01) than that used on either the rural or the suburban material.

9) A significant background/scale interaction (p less than 0.05) was revealed (see Table XIV). Duncan's new multiple range test was applied to the mean time scores for each of the background/scale conditions to determine the significant groupings. Figure 23 contains the time scores plotted for each background at each scale. The three circles areas represent the conditions yielding similar performance levels. This illustration shows that background is a primary determiner of performance only at a scale of 1:20,000.

10) No significant differences exist between the mean number of commission errors as a function of the display method, quality of the imagery, scale of the photography, or type of background contained in the scenes.

Performance data of the photointerpreters show:

1) The percentage of targets correctly detected was essentially the same with both display methods (50.3 percent with apparent motion and 42.1 percent with side-by-side display).

2) A significantly larger proportion (p less than 0.01) of the targets was correctly detected with the high-quality imagery (58.5 percent) than with the degraded imagery (33.9 percent). The magnitude of this difference (about 25 percent) is comparable to the difference of 18 percent found between these two conditions for the non-photointerpreters.

3) The percentage of targets correctly detected with photographs representing a scale of 1:10,000 was 50.0, and with photographs representing a scale of 1:40,000, 42.5 percent were reported. The 7.5 percent of additional targets detected with the larger-scale photography was not statistically significant (see Table XIV).

4) The complexity of the background did not significantly affect detection performance. Percentages of detections were 46.5, 43.6, and 48.6 for the rural, suburban, and industrial backgrounds, respectively.

5) Mean inspection time for each comparative pair was significantly longer (p less than 0.05) with the side-by-side display than with the apparent-motion display. The saving of about 31 seconds per inspection (159.6 seconds with side by side as opposed to only 128.0 seconds with apparent motion) was nearly the same in magnitude as the 25-second saving found with the non-photointerpreters.

6) Mean inspection time did not vary with the quality of the imagery: 145.0 seconds were required with maximally degraded imagery, and 142.7 seconds with the highest-quality material.

7) The scale of imagery was a significant determinant (p less than 0.01) of the time spent inspecting each pair of photographs (see Table XIV). Subjects averaged about 0.75 minute longer inspecting the smaller-scale photography (166.7 seconds average) than when viewing the larger-scale photography (120.9 seconds average).

8) Mean inspection time per comparative pair was not significantly related to the background complexity (rural, 124.5 seconds; suburban, 158.9 seconds; and industrial, 148.0 seconds).

9) The mean number of commission errors per comparative pair was not significantly affected by the display method (0.93 for apparent motion and 1.18 for side by side), by the quality of the imagery (1.01 for high-quality material and 1.09 for low-quality photographs), or by the background complexity (rural, 0.91; suburban, 1.19; industrial, 1.06).

10) A significantly greater number (p less than 0.05) of commission errors were made with the 1:40,000-scale photographs as compared with the commission response recorded with the 1:10,000-scale materials. Approximately one additional commission error was made for every two comparative pairs with the smaller-scale photography (0.81 commission errors per pair at 1:10,000 as compared to an average 1.29 commission errors with 1:40,000-scale imagery).

A direct comparison between the performance of photointerpreters and non-photointerpreters was not possible because the treatments and treatment levels experienced by the subjects of each group were not the same. Specifically, the major differences between the presentations to the two groups are that, although the stimulus parameters used were the same for both groups, the photointerpreters received only two of the three treatment levels of image quality and scale. Furthermore, they each participated under all treatments and treatment levels, whereas each subject in the non-photointerpreter group experienced all treatment levels except scale, for which they observed only one of the three treatment levels.

A limited comparison can be made, however, for treatment levels common to both groups. Bartlett's test for the homogeneity of variance between groups was applied to each of the dependent measures. Group variances did not differ significantly for either detections ($\beta' = 2.99$) or time ($\beta' = 3.31$). Then, test ratios were computed to test for significance between means of the two groups. None of the test ratios revealed significant differences. This is summarized in Table XV. Apparent-motion and side-by-side methods were pooled for this analysis.

Table XV SIGNIFICANCE OF THE DIFFERENCES BETWEEN EXPERIENCE LEVEL MEANS

% CORRECT DETECTIONS							
	NON-P.I.		P.I.		d	t	p*
	M	σ	M	σ			
1:10,000	57.7	39.3	50.0	39.7	8.1	1.31	NS
1:40,000	28.8	30.1	42.5	30.5	13.6	0.91	NS

MEAN TIME PER PAIR (SECONDS)							
SCALE	NON-P.I.		P.I.		d	t	p*
	M	σ	M	σ			
1:10,000	117.9	51.9	120.9	52.8	2.1	0.63	NS
1:40,000	183.6	79.6	166.7	77.0	17.2	1.41	NS

* For df = 156: p 0.05 = 1.97
p 0.01 = 2.60

Bartlett's test for homogeneity of variance revealed that the non-photointerpreter population was significantly less variant ($\sigma^2 = 0.86$) than the experienced group ($\sigma^2 = 2.17$) in the number of commission errors made ($\beta' = 40.08$, p less than 0.01). Thus, a nonparametric median test was applied to test the differences between the group medians. The resultant chi-squares of 0.028 for the 1:10,000-scale material and 0.73 for the 1:40,000-scale material were not significant.

CONCLUSIONS

Experiment II was designed to test the relative effectiveness of the two display methods — apparent motion and side by side — for target-change detection by photointerpreters and non-photointerpreters. The latter group veiwed the comparative-cover photography at three scales (1:40,000, 1:20,000, and 1:10,000) and three levels of image quality (blur). The photointerpreters saw only the highest and lowest levels of scale and blur. The photography for both groups contained an equal number of samples of three types of background: industrial, surburban, and rural. The performance measures obtained were correct detections, false detections (errors of commission), and time required for the inspection of each pair.

The apparent-motion method was significantly faster only with respect to inspection time (see Tables XIII and XIV). This was true for both groups. The apparent-motion method yielded more correct detections from both groups, but the difference was not statistically significant.

Blur was a significant variable in the percentage of correct detections: fewer targets were detected with each level of degradation. Although the differences in inspection time as a function of blur were not statistically significant, the values obtained are ordered in correspondence to the image quality. This may mean either that there are fewer visible changes with increased blur (thus requiring less inspection time) or that the observers are less inclined to search the pictures when image quality is poor. It might be a combination of both things. However, it is possible that performance would be different in an operational situation that demanded an exhaustive search with low-quality photography.

Photographic scale presents some unique difficulties for the systematic investigation of its effects on target-change detection. The scale of a photograph cannot be changed without changing, at the same time, the value of some other physical parameter. If a photograph of 1:20,000 scale is enlarged to 1:10,000 scale, either the format size must be increased, or the ground coverage must be reduced. The same format size was maintained in Experiment II because: (1) constant format size was judged to be more typical of the operational situation, and (2) it appeared desirable to keep the field of visual search constant. The effect of this restriction is to allow ground coverage to vary with scale and, along with it, the number of changes occurring in the photograph. The scale in which the terrain is represented is thus not the sole determiner of the numerical values of the response measures.

For both photointerpreters and non-photointerpreters, inspection time was inversely related to scale; variance due to this factor reached significance at the 99-percent level of confidence for the former group. (Strictly speaking, there is one chance in 100 that the observed difference is a normal deviation in a single stimulus population. Differences in "scale" refer to whatever changes occurred as attempts were made to manipulate this dimension of the photography.)

The difference in errors of commission was statistically significant for scale in the photointerpreter group, and the difference was in the expected direction. This group also evidenced an expected drop in the percentage of correct detections with the smaller scale, although this difference was not significant at the 0. 05 level.

With the non-photointerpreter group, the percentage of correct detections and frequency of false detections, although not significant, corresponded to predictions for the highest and lowest scales, but not the intermediate scale. There is no way to determine whether this discrepancy between predictions and observations would have occurred with the photointerpreters because they were not presented the 1:20, 000-scale photography.

The difficulties associated with varying the scale of the photography are reflected in the number of target changes occurring with the different scales used in this experiment. These changes were 39, 58, and 82 for the 1:10, 000, 1:20, 000, and 1:40, 000 scales, respectively, in the pairs presented to the non-photointerpreters. For photointerpreters, there were 60 changes in the 1:10, 000-scale pictures and 102 in the 1:40, 000-scale material. Because of these differences inextricably tied in with scale, the interpretation of the data is less straightforward than it might otherwise have been. For example, Table XII shows that the non-photointerpreters took a little less than two thirds as long to inspect the 1:10, 000-scale photography as they did for that seen at 1:40, 000 scale. However, in spite of the longer time with the smaller scale, these observers are spending less time with this scale if we consider inspection time in terms of the number of target changes represented in each scale. In these terms, they are spending only three fourths as much time with the 1:40, 000 material as with the 1:10, 000 material; the situation considered in this way is the reverse of what it appears to be in Table XII.

The percentage of correct detections for these two scales in the same table shows that close to twice the percentage was obtained for the 1:10, 000 scale as for the 1:40, 000 scale. The actual number of changes detected is 126 for the former and 136 for the latter, a larger number for the smaller scale but a smaller percentage, by half. Further consideration of detections in terms of the number reported per unit time reveals that performance with the smaller scale (1:40, 000) is close to 70 percent as good as that with the larger scale (1:10, 000) instead of only 50 percent (see Figure 27).

An additional problem arises with the generation of photographic stimuli of different scales that must be done in the laboratory rather than originally photographed at the desired scale. The problem is that if the scale must be increased from that of the original, a loss occurs in resolution, and this loss might increase the difficulty of the change detection task. In the generation of stimuli for Experiment II, 38 of the 46 samples of photography used were originally 1:20, 000 scale or close to it (see Appendix III), and in the 1:10, 000 test material, 12 samples of 1:20, 000 photography were used and one sample of 1:40, 000.

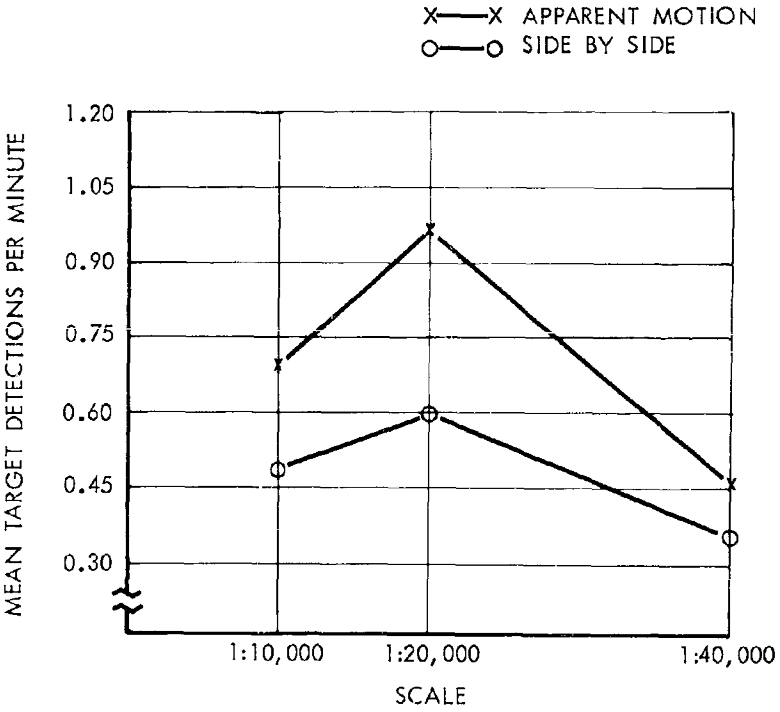


Figure 27 MEAN TARGET DETECTIONS PER MINUTE AS A FUNCTION OF SCALE Non-P.I.

This would be expected to result in poorer quality at the largest scale than at the other two scales and might account for the fact that change detection performance at the 1:20, 000 scale was better overall than at the 1:10, 000 scale.

The problem of differences in the number of target changes also occurs when background complexity is varied. There are 75 target changes in the industrial-background material, 60 in the surburban, and 44 in the rural. If complexity is assumed to vary directly with the number of target changes, the suburban material is nearly equidistant from the industrial and rural backgrounds on the complexity continuum. Again, Table XII shows that inspection time increases with the number of changes, but it does not rise in proportion to the changes. As in the case with the scale factor, the non-photointerpreters spend proportionately less time with the photographic pairs that contain more changes.

Referring, as before, to the percentage of correct detection figures (Table XII), this performance measure bears no simple relationship to background complexity. The number of correct detections per unit time as a dependent measure (Figure 28) results in a clear and direct relationship between performance and the frequency of target change in the stimulus material. Furthermore, in a plot of the detections per unit time for the three scales with background type as the parameter, the curves contrast markedly with those shown in Figure 23, which shows inspection time per scale where the time measure is not adjusted for the number of detections. The lower curve (rural) rises sharply in this plot, whereas it is essentially flat when the number of detections per unit time is the dependent measure (see Figure 29). The other two curves are correspondingly displaced by this procedure.

The decision as to which performance measure is best depends, of course, on considerations other than those presented here. The user of the information supplied by this study will decide whether it is preferable to use one measure or another. Either kind of situation could occur — information about a large or complex area is needed rapidly with relatively little concern about omissions; or, the maximum probability that whatever relevant changes there are will be detected by the photointerpreter is essential. The purpose in presenting the data in more than one way is to extend its utility and permit an easier application to a broader range of practical situations. This is a task the authors are better able to accomplish than the reader who acquires the report because of a specific and urgent need.

The question of the effect of artificially introduced targets on performance was raised in the "Conclusions" discussion section for Experiment I. In Experiment II, artificial target changes were added to those existing in the original photography. Table XVI shows the percentage of targets introduced by the artist and the correct detections made of them as a percentage of all correct detections.

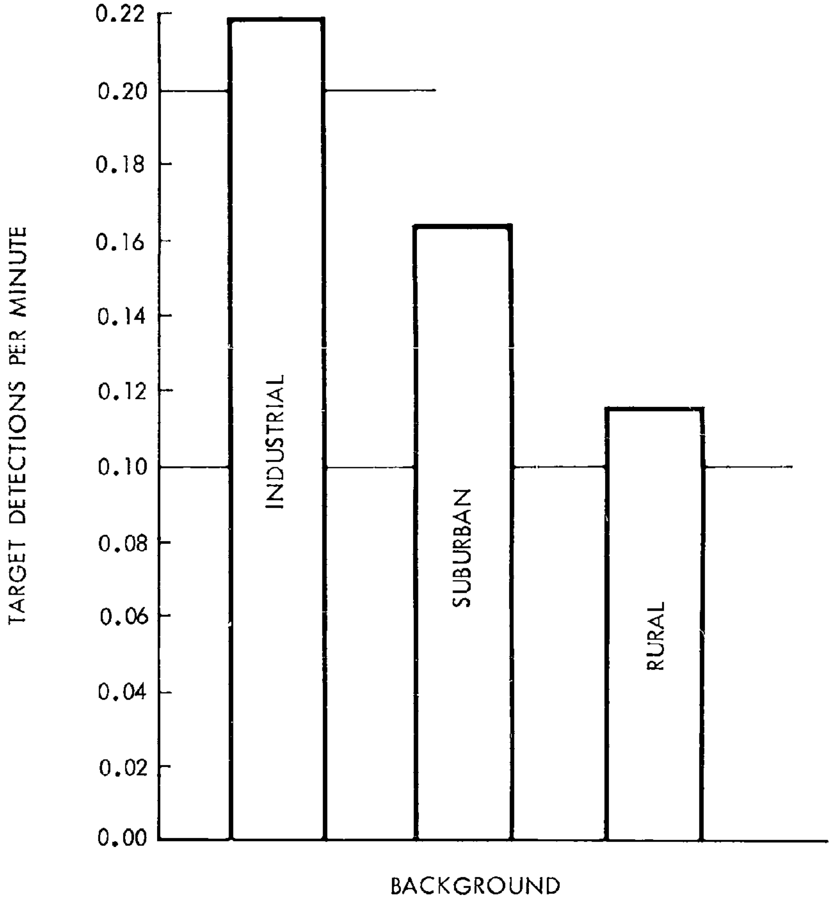


Figure 28 TARGET DETECTIONS PER MINUTE AS A FUNCTION OF BACKGROUND

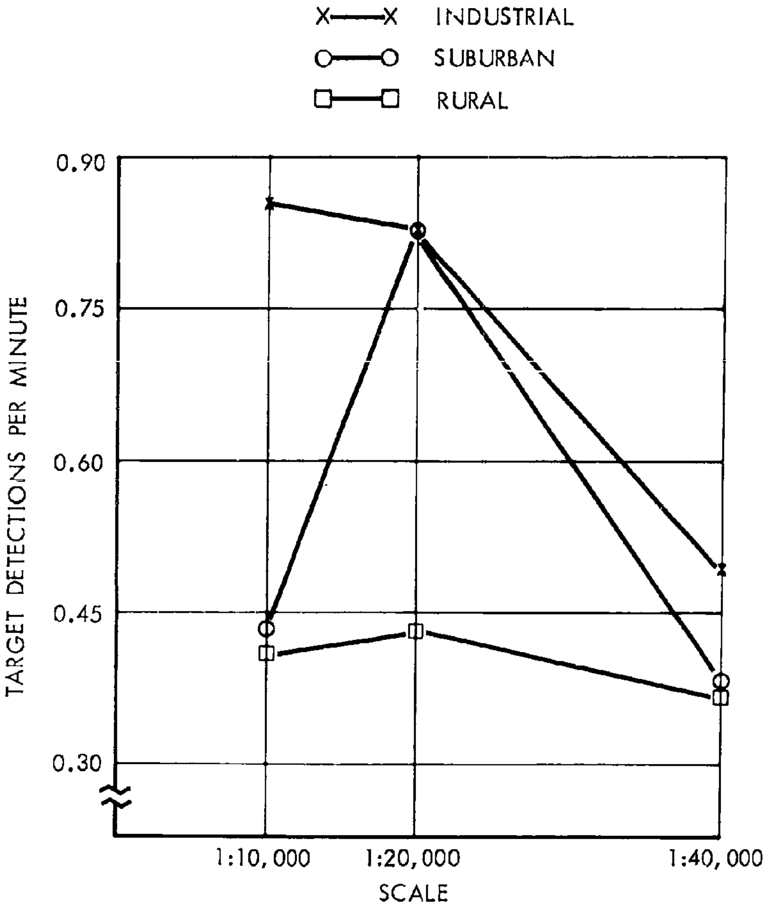


Figure 29 TARGET DETECTION PER MINUTE AS A FUNCTION OF SCALE FOR THREE TYPES OF BACKGROUND

Table XVI FREQUENCY OF OCCURRENCE OF ARTIFICIAL TARGETS AMONG REAL TARGETS AND FREQUENCY OF DETECTIONS

DISPLAY SCALE	PERCENT OF TARGET OCCURRENCES			PERCENT OF DETECTIONS	
		ARTIFICIAL	REAL	ARTIFICIAL	REAL
1:10,000	P.I.	18	82	23	77
	Non-P.I.	30	70	45	55
1:20,000	Non-P.I.	32	68	34	66
1:40,000	P.I.	13	87	14	86
	Non-P.I.	17	83	17	83

The only real difference between the frequency of artificial targets and the proportion of correct detections attributable to them occurs in the 1:10,000-scale condition. The discrepancy at this scale may be due to the enlargement needed to produce the test material (i.e., the artificial targets were less blurred than the inherent changes blurred through enlargement). Although the experimental design did not permit the inclusion of performance measures from both observer groups in a single analysis of variance, a series of t-ratios were computed for correct detections and inspection times (Table XV). These ratios revealed no significant differences between the photointerpreters and the non-photointerpreters for the two measures. Similarly, a median test of the difference between groups in false detections did not reach statistical significance.

An inspection of the graphic data (see Figures 24, 25, and 26) leads one to suspect that greater control over the within-subject or within-group sources of variability would result in the demonstration of statistically significant differences in some instances. For example, there appears to be a general tendency for the non-photointerpreters to be slightly superior in target-change detection with photography of 1:10,000 scale, but markedly inferior to the photointerpreters with the 1:40,000 scale. The non-photointerpreters also appear to take a little longer with the 1:40,000 scale. Of the eight comparisons of errors of commission shown in Figure 26, only once is the frequency greater for the photointerpreters. Thus, in overall performance, the photointerpreters appear to be superior, with this superiority more evident with the smaller scale (1:40,000).

The data obtained under the conditions of Experiment II indicate that the apparent-motion display is superior to the side-by-side display in the time expended by non-photointerpreters and photointerpreters to detect change in comparative-cover photography (p less than 0.05). There is no statistically significant difference between the two display methods in their effect on the percentage of correct detections and the frequency of false detections for the analyses of variance summarized in the "Results" section of Experiment II. This method of analysis was selected at the time the experimental design and methodology were developed. Despite the compromises imposed on the methodology by the limited stimulus material, the planned analysis was executed. However, there is some cause to question the desirability of using percentages based on such small numbers as those shown in Appendix V.

In answer to this, at the cost of sacrificing the analysis of one factor, the scores for background complexity were combined before percentages were computed. The results of this analysis for the non-photointerpreters are summarized in Table XVII. Blur and scale were significant, as before, but with larger F ratios. Moreover, the main effect of display method shows the apparent-motion method to be significantly superior to the side-by-side method. The means for these treatments according to this second analysis are shown in Table XVIII.

Since all three factors — scale, blur, and method — were statistically significant in the second analysis (as opposed to just two factors, blur and scale, in the first), it appears desirable that further studies be designed so that detection scores under all combinations of the treatment conditions are comparable without a percentage transformation. This approach would reduce an important source of error variance, the use of percent-correct detection scores, which are highly sensitive to minor performance differences when observations are limited in number.

The character of the stimulus material available for this experiment imposed severe conditions for testing the display methods. Although the same photography was used for both displays, the effect was more likely to be severe for the apparent-motion display than for the side-by-side display. The reason for this is that, with the sensitivity of the apparent-motion method to any type of change, a large amount of irrelevant change requires more extensive search for relevant changes. When this irrelevant "motion" exceeds some value, the requirements for search and discrimination in the apparent-motion display will tend to nullify the gains obtainable with this technique under conditions with less noise. The photography used in Experiment II spanned a number of years for most comparative pairs and, in this sense, may not be typical of current comparative-cover photography where significant target changes occur in considerably shorter time, frequently in a matter of days.

Improvements in reconnaissance systems could, presumably, result in the acquisition of comparative-cover photography, which is more amenable to the apparent-motion method of display. Thus, in addition to the development of better sensors and sensor platforms, attention would be directed toward the better duplication of flight path, altitude, ground speed, time of day, and any other factors that produce irrelevant visual noise when uncontrolled. If the photointerpretation function is the bottleneck in the intelligence system, efforts to control these factors may prove fruitful.

Table XVII SUMMARY OF ANALYSIS OF VARIANCE
Correct Detections With Background Complexities Combined Before Percentage Transformations

NON-P.I. GROUP

SOURCE OF VARIATION	df	ms	F
Between Subject Total	(17)		
Scales (S)	2	12365	13.00**
Error (Between S's Within Groups)	15	951	
Within Subject Total	(90)		
Methods (M)	1	1281	4.372*
Blurs (B)	2	3006	10.259**
M x S	2	141	
M x B	2	202	
S x B	4	285	
M x S x B	4	160	
Within Subject Error	75	293	
TOTAL	107		

* Significant at 0.05 Level
** Significant at 0.01 Level

Table XVIII MEAN PERCENT DETECTION SCORES FOR NON-P.I.

Terrain Complexities Combined

SCALE 1:10,000

IMAGE QUALITY	AM	SXS	M
Hi	73.5	62.7	70.2
Med	56.3	46.8	51.6
Lo	37.2	45.5	41.3
M	56.8	52.0	54.4

SCALE 1:20,000

IMAGE QUALITY	AM	SXS	M
Hi	76.2	60.8	68.5
Med	65.2	60.3	62.8
Lo	64.0	49.8	56.9
M	68.4	57.0	62.7

SCALE 1:40,000

IMAGE QUALITY	AM	SXS	M
Hi	38.3	31.5	34.9
Med	28.5	23.2	25.7
Lo	21.7	20.5	21.1
M	29.5	25.1	27.3
G.M.	51.6	44.7	48.1

EXPERIMENT III

INTRODUCTION

The results of previous research would seem to indicate that the greater the amount of "visual noise" or irrelevant change appearing between the two samples of any comparative pair of photographs, the less effective is the apparent-motion display method in facilitating rapid, accurate, and complete extraction of intelligence. In an attempt to explore this stimulus parameter more systematically, a third experiment was conducted in which the time lapse between comparative coverages was systematically varied and target-detection performance by photointerpreters and non-photointerpreters was assessed using both side-by-side and apparent-motion display systems. If the assumption is accepted that with longer time lapses between successive coverages there generally will be more numerous irrelevant differences (those not critical to successful completion of the military mission) occurring between the two photographs, a prediction would be that interpretation would take longer and be less accurate and complete for longer time-base materials. It might further be hypothesized that, because of the enhancement and attention-demanding nature of differences between the two photographs with the apparent-motion display method, such interference might be particularly deleterious to inspection performance with this display system.

SUBJECTS

Two groups of 12 subjects each served as observers in this experiment. One group (non-photointerpreters) was composed of shop and laboratory technicians and professional personnel from within the Bioastronautics organization of The Boeing Company. These observers had neither formal training nor extensive experience in photointerpretation, although eight had also participated in Experiment II. The second group consisted of 12 Boeing employees who were trained or experienced professional photointerpreters. No member of this group was currently active in photointerpretation as a regular part of his job. Of these 12 observers, two had participated only in Experiment II, one had served only in Experiment I, and five had served as observers in both Experiments I and II.

APPARATUS

The display equipment used to present the comparative pairs in both side-by-side and apparent-motion formats was the same as that employed in the two previous studies. All optics were cleaned, and the light sources were replaced and calibrated before the first data were collected.

The response system was the same as that described earlier. Since only a single target class (antiaircraft artillery) was designated for detection and reporting, that portion of the display and response systems introduced previously for purposes of target identification was not utilized in the present study.

STIMULUS MATERIAL

Four vertical photographic coverages of a 3.6-mile-long and 2.2-mile-wide strip of terrain along the east shore of Lake Washington near Seattle, Washington, was purchased from a local aerial survey service. The original photography was taken from an altitude of approximately 12,000 feet with a camera having a 6-inch focal length. The working prints were enlargements to approximately a 1:7,500 scale, resulting in an 18- by 30-inch format size. The earliest of the four coverages (A) was taken on 23 February 1962 and the second coverage (B) was taken on 25 July 1962. The third picture (C) was taken on 24 December 1962 and the most recent coverage (D) was taken on 17 May 1963. Thus, comparative pairs consisting of samples A-B, A-C, and A-D represented time lapses of 147, 292, and 461 days, respectively, or time bases of approximately 5, 10, and 15 months. These four coverages are shown at reduced scale in Figures 30, 31, 32, and 33.

The dominent terrain features were those typically classified as suburban. Ground activities observed during the 15-month period sampled ranged from the construction of light manufacturing and production complexes to relatively unchanged rural areas. The most substantial portion of the photography depicted the rapid development of suburban housing projects. The original photography was of good quality and only a slight degradation resulted from the 3.2x enlargement.

From the 18- by 30-inch working prints representing each coverage (A, B, C, and D), 12 comparable 4- by 4-inch sections were selected. Four of these sections are shown in Figure 34. Three antiaircraft artillery installations were artistically introduced within each 4- by 4-inch area on coverages B, C, and D. The schematic shown in Figure 35 was used as a model for the drawing of the emplacements. The location of the artillery batteries within any given segment of a photograph was the same for coverages B, C, and D (the comparison photographs); but none of the emplacements incorporated on coverage A (the standard) were coincident with any of those appearing in the three comparison samples.

Negatives of each of the 48 areas (12 areas on each of the four coverages) were prepared, and positive transparencies were made from them. A minimal amount of rectification and scaling (involving only 17 of the 48 negatives) was performed in the photographing process to compensate for slight differences in aircraft altitude and positional differences relative to the nadir on the original photography.

Each transparency was then sandwiched between two machined plates of 0.125-inch plexiglass for accurage insertion and positioning in the display system.

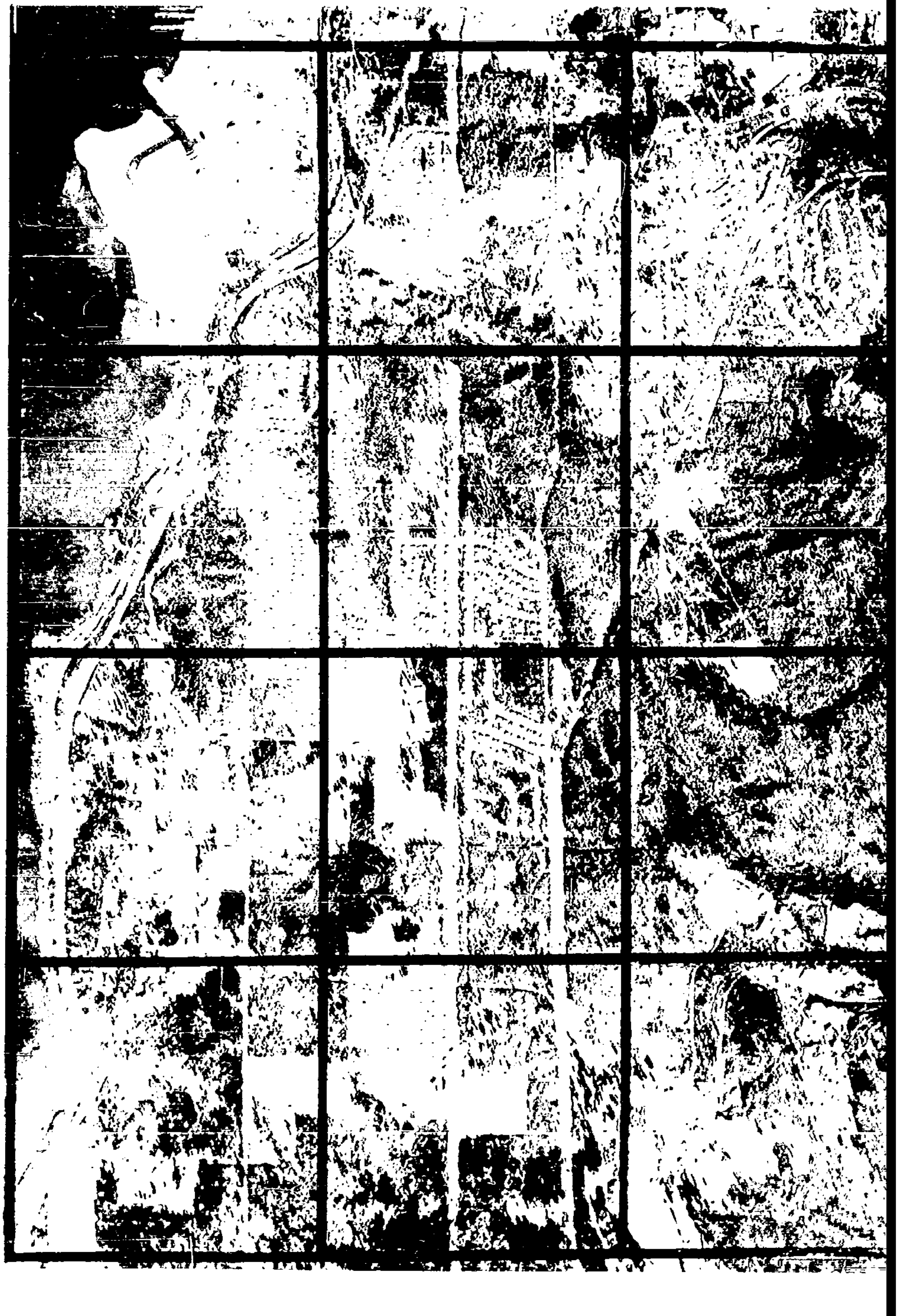


Figure 30 EARLIEST PHOTOGRAPHIC SAMPLE FOR EXPERIMEN

Figure 31 FIVE-MONTH SAMPLE FOR EXPERIMENT III

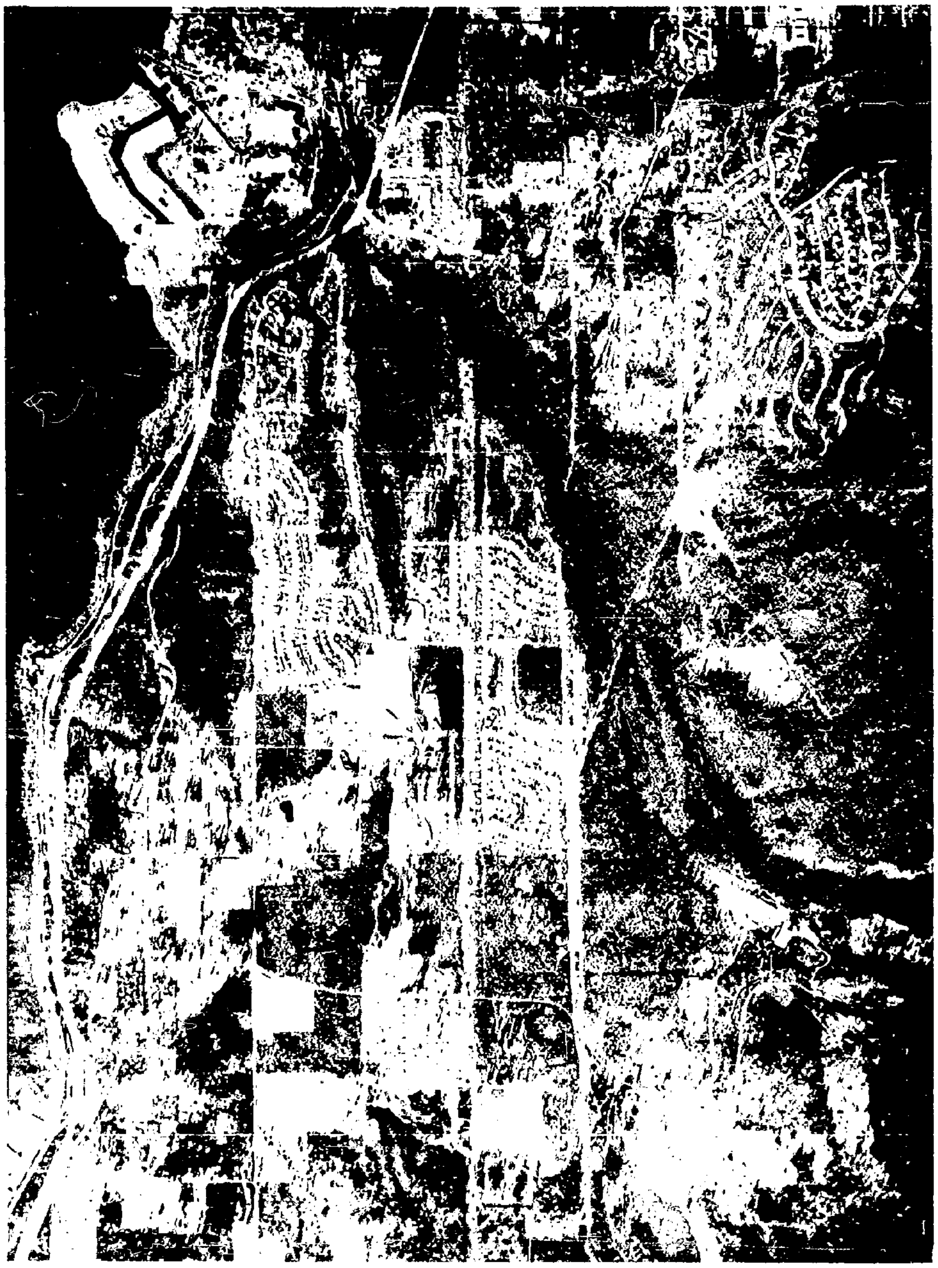
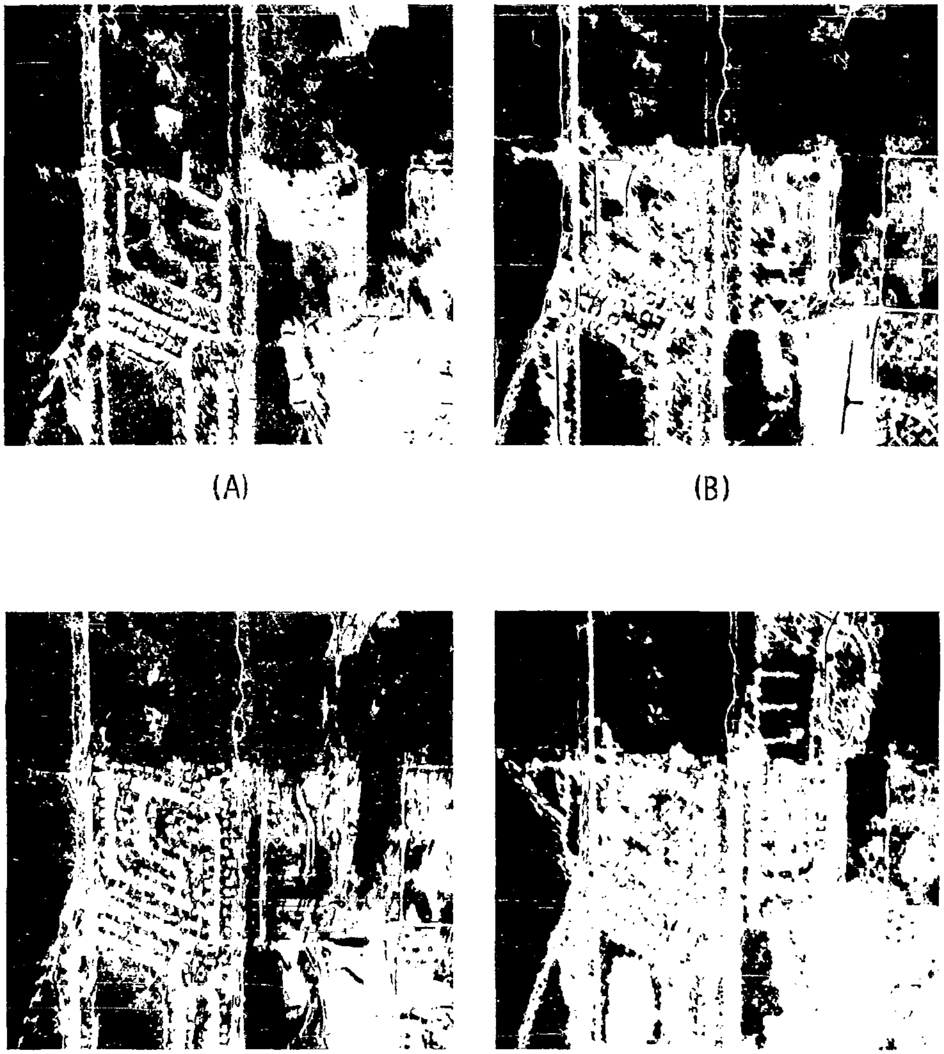


Figure 32 TEN-MONTH SAMPLE FOR EXPERIMENT III

Figure 33 FIFTEEN-MONTH SAMPLE FOR EXPERIMENT III



(A)

(B)

(C)

(D)

Figure 34 TIME LAPSE SAMPLES OF
AERIAL PHOTOGRAPHS USED IN EXPERIMENT III

(A) "Zero Time", (B) 5 Months, (C) 10 Months, and (D) 15 Months;
11 Antiaircraft Sites Are Included In These Photos

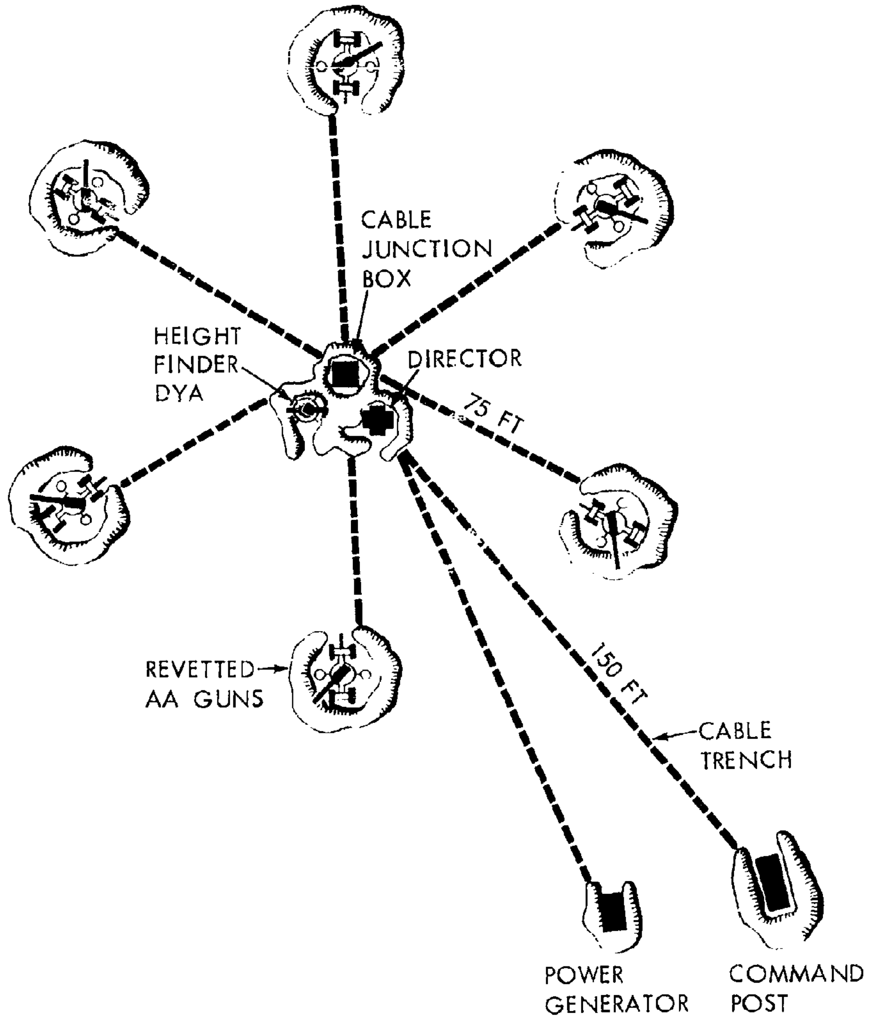


Figure 35 SCHEMATIC REPRESENTATION OF A TYPICAL ANTIAIRCRAFT EMPLACEMENT

TRAINING

Those subjects who had not previously been trained in conjunction with their participation in the earlier experiments were given the training procedure described in detail for Experiment I. Subjects having received previous training and experience with the display apparatus and response system were given a brief review and refamiliarization with the display system and use of the response panel. Three sets of the "high visual noise aerial photographs" were presented and knowledge of performance provided.

INSTRUCTIONS

The following instructions were presented to each observer immediately before beginning the data collection:

> The specific targets you will be asked to search for in the aerial photographs to follow are ANTIAIRCRAFT ARTILLERY. Please study this schematic of a typical antiaircraft emplacement while I describe some of the identifying characteristics of such an installation.
>
> The term ANTIAIRCRAFT ARTILLERY is applied to ground and shipborne weapons and materials used to locate, fire on, and destroy enemy aircraft.
>
> Antiaircraft artillery batteries generally give the interpreter little difficulty because of their characteristic layout when emplaced for firing. The normal battery will consist of six guns, each found in a circular revetment, distributed around fire-control equipment which may include visual height-range finders, gun directors, radar and power plants.
>
> The COMMAND POST may be sited either in the center or behind the guns, but usually within 150 feet. The command post is the control center for the battery and can be found in a van-type vehicle or in earthen or concrete bunkers.
>
> COMMUNICATIONS CABLES are buried in trenches which run from the command post to the gun area and then split into various cables leading to each gun.
>
> The POWER for this system may be supplied by either generators or batteries. Power cables may be underground or overhead, supported by poles.
>
> Permanent pathways are sometimes laid down in the case of fixed batteries and usually show up with a light tone when compared with the surrounding country.
>
> Since the main function of antiaircraft artillery is to protect vital ground targets from attack by aircraft, the guns are usually located

on hilltops, in open fields, lots or parks, or on top of buildings to allow a 360-degree field of fire. Camouflage is not normally used but emplacements may be partially camouflaged on the sides.

It will be your task to detect and report all instances where antiaircraft batteries have either been added or removed from the area being searched. Work as fast as you can but be sure you have found all the targets before signalling completion. Speed and accuracy are weighted equally in the evaluation of your performance.

EXPERIMENTAL DESIGN

The basic experimental design is presented schematically in Figure 36. Each photointerpreter inspected all twelve of the 4- by 4-inch sectors comprising the total area. Six of these were viewed side by side and six were seen in apparent motion. Of the six areas searched by each photointerpreter under either display system, two represented the 5-month time base, two represented the 10-month time base, and two represented the 15-month time base. Because there were 12 independent area samples available, it was possible to obtain two performance samples from each photointerpreter under each of the display method times time-base conditions without viewing each area more than once.

The display methods were alternated after every two presentations. Display-method order was counterbalanced between subjects within each group. Thus, the first subject would inspect the first two comparative pairs in side-by-side presentation and the next two comparative pairs in apparent motion while the second subject would see the first two pairs in apparent motion and the next two side by side.

To prevent any systematic biasing of the data because of the presentation order of the three different time bases, a Latin square design was applied in assigning the time-base sequence within and between subjects in each group.

The assignment of specific coverage areas (from within the 12 sections comprising the standard photograph, A) to subject times display method times time-base conditions was random, with the restriction that each area was to be inspected by only two subjects within each group and under each of the six display method times time-base conditions.

RESULTS

The performance measures obtained from each observer were the total time required to inspect each comparative pair and the number of detections reported for each. Since ground truth (the actual number of targets in the area) was known, it was possible to determine completeness (percent of targets detected) as well as the number of errors of commission. Table XIX summarizes the percentage of correct detections, the mean time per comparison, and the mean number of errors of commission.

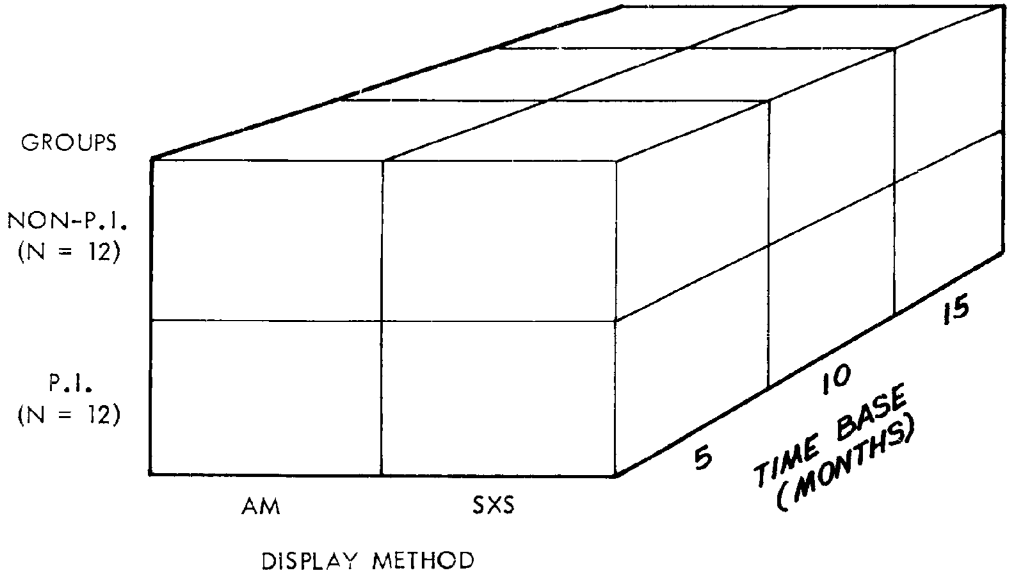


Figure 36 SCHEMATIC REPRESENTATION OF DESIGN FOR EXPERIMENT III

Table XIX MEANS OF PERFORMANCE MEASURES FOR EXPERIMENT III

(A) Percent Detections

	5-MONTH BASE		10-MONTH BASE		15-MONTH BASE		M
	AM	S x S	AM	S x S	AM	S x S	
Non-P.I. Group	33.3	42.7	39.6	36.5	28.1	39.6	36.6
P.I. Group	38.5	39.6	39.6	30.2	33.3	34.4	35.9
M =	38.5		36.5		33.8		

(B) Mean Time Per Pair (Seconds)

	5-MONTH BASE		10-MONTH BASE		15-MONTH BASE		M
	AM	S x S	AM	S x S	AM	S x S	
Non-P.I. Group	83.0	102.7	94.7	101.0	85.5	101.5	94.7
P.I. Group	98.2	98.2	99.7	101.8	96.0	101.5	99.2
M =	95.5		99.3		96.1		

(C) Mean Errors of Commission Per Pair

	5-MONTH BASE		10-MONTH BASE		15-MONTH BASE		M
	AM	S x S	AM	S x S	AM	S x S	
Non-P.I. Group	0.167	0.125	0.167	0.167	0.250	0.417	.215
P.I. Group	0.333	0.375	0.292	0.375	0.417	0.500	.382
M =	0.250		0.250		0.396		

	DISPLAY METHOD	
	AM	SxS
Percent Detections	35.40	37.2
Mean Time (Seconds)	92.8	101.1
Commission Errors	.271	.326

The analysis of variance based on the number of correct detections (Table XX) reveals no significant differences either as a function of presentation method (35.4 percent with apparent motion as compared to 37.2 percent with side by side), level of experience of the subjects (36.6 percent for non-photointerpreters and 35.9 percent for photointerpreters), or the time base between comparative samples (38.5, 36.5, and 33.8 percent for time bases of 5, 10, and 15 months, respectively).

Table XX SUMMARY OF ANALYSIS OF VARIANCE OF CORRECT DETECTIONS

SOURCE OF VARIATION	df	ms	F
Between Groups (G)	1	0.11	—
Between Display Methods (D)	1	0.69	—
Between Time Bases (T)	2	1.70	—
G x D	1	4.00	1.31
G x T	2	0.36	—
D x T	2	3.70	1.21
G x D x T	2	0.09	—
Error Variance	132	3.05	—
TOTAL	143		

Similarly, the analysis of inspection time required to search each comparative pair (Table XXI) revealed no significant differences either as a function of the display method involved (92.8 seconds with apparent motion, as compared with 101.1 seconds with the side-by-side display), or the experience level of the observer (94.7 seconds required by non-photointerpreters and 99.2 seconds required for photointerpreters), or the time lapse between coverages (95.5, 99.3, and 96.1 seconds for the 5-, 10-, and 15-month separations, respectively).

The mean number of commission-error responses made by the photointerpreters (0.382 per comparative pair) was significantly greater (p less than 0.05) than the mean number committed by the non-photointerpreters (0.215). See Table XXII for the summary of the analysis of variance. The rate at which commission errors were made was not, however, related to the display method (0.271 for apparent motion and 0.326 for side by side) or to the time base of the photography (0.250, 0.250, and 0.396 for time bases of 5, 10, and 15 months, respectively) (See also Figures 37 and 38).

Table XXI
SUMMARY OF ANALYSIS OF VARIANCE OF INSPECTION TIMES

SOURCE OF VARIATION	df	ms	F
Between Groups (G)	1	0.81	—
Between Display Methods (D)	1	2.72	1.62 N.S.
Between Time Bases (T)	2	0.22	—
G x D	1	1.32	—
G x T	2	0.03	—
D x T	2	0.17	—
G x D x T	2	0.21	—
Error Variance	132	1.68	—
TOTAL	143		

Table XXII SUMMARY OF ANALYSIS OF VARIANCE OF ERRORS OF COMMISSION

SOURCE OF VARIATION	df	ms	F
Between Groups (G)	1	4.0	4.55*
Between Display Methods (D)	1	0.44	—
Between Time Bases (G)	2	1.36	1.54
G x D	1	0.03	—
G x T	2	0.09	—
D x T	2	0.20	—
G x D x T	2	0.11	—
Error Variance	132	0.88	—
TOTAL	143		

* Significant beyond 0.05 level.

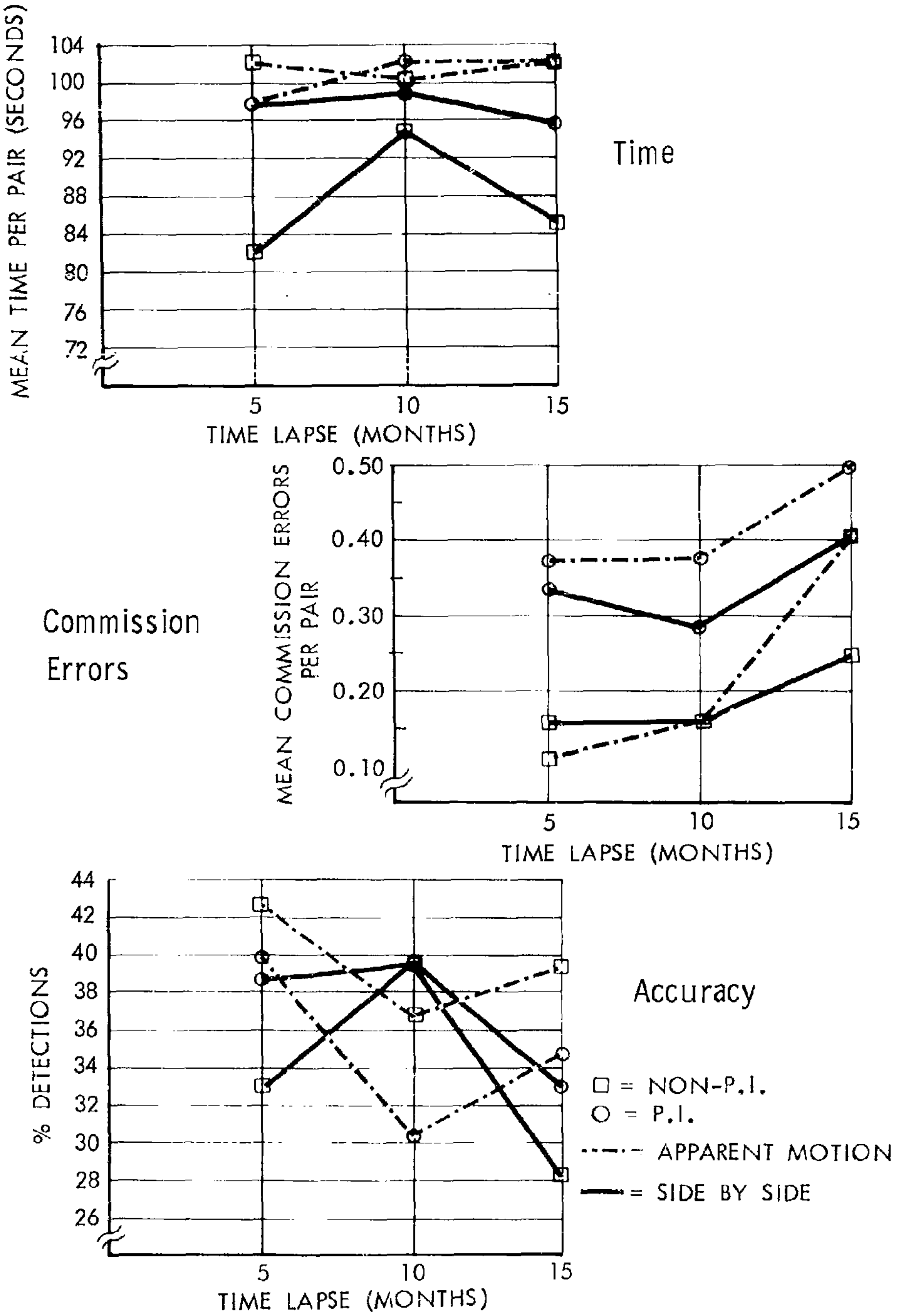
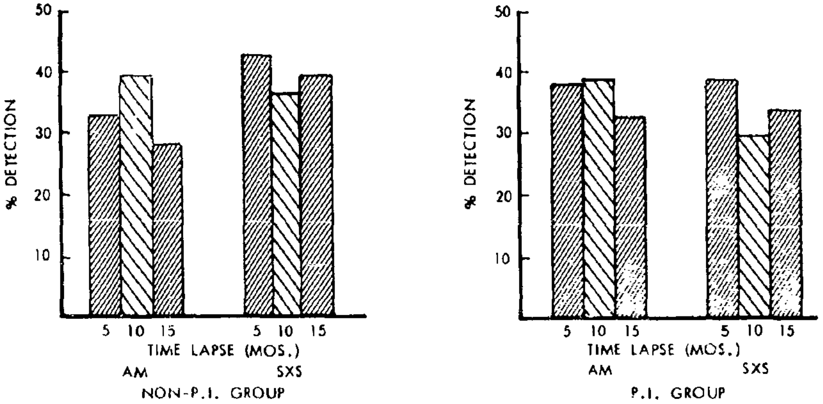
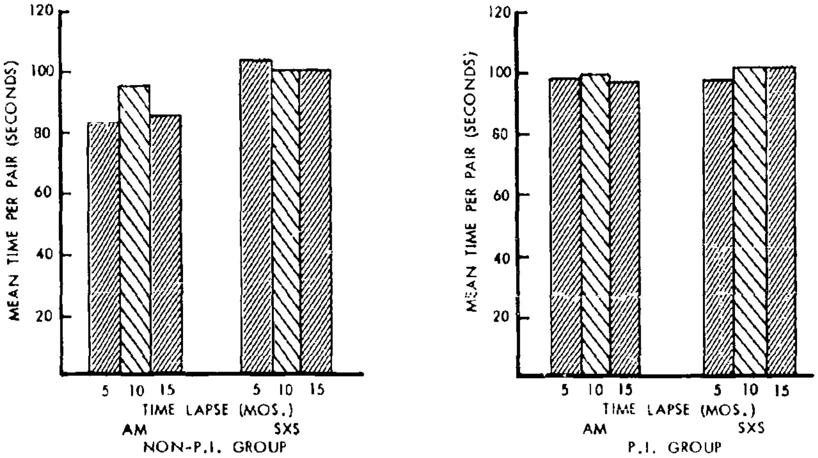


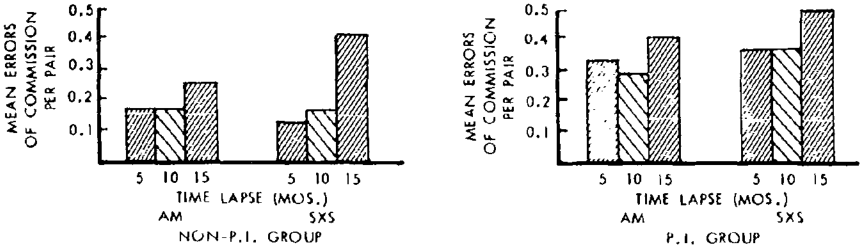
Figure 37 PERFORMANCE PLOTTED AS A FUNCTION OF TIME LAPSE



(A) Percent Detections For Non-P.I. and P.I. Groups With Three Time Lapses And Two Display Methods



(B) Mean Time Per Pair For Non-P.I. And P.I. Groups With Three Time Lapses And Two Display Methods



(C) Mean Errors Of Commission Per Pair For Non-P.I. And P.I. Groups With Three Time Lapses And Two Display Methods

Figure 38 BAR GRAPHS OF PERFORMANCE AS A FUNCTION OF TIME LAPSE

CONCLUSIONS

The major purpose of Experiment III was to compare the effects of the apparent-motion and side-by-side display methods upon target-detection performance where the comparative coverages spanned 15 months in three equal intervals. As in the previous experiments, both experienced and inexperienced photointerpreters were tested.

The statistical analysis of the empirical data suggests: (1) that neither display method is superior to the other, (2) that target-change detection performance does not vary for time bases ranging from 5 to 15 months, and (3) that nonphotointerpreters make fewer false detections than photointerpreters, but that these two groups do not differ in the number of correct detections or inspection time.

The question of primary concern is the extent to which the observed results may be applied to the photointerpretation task in general. This involves a critical data appraisal for the purpose of examining alternate hypotheses which may account for the obtained results. Only one statistically significant difference was apparent in the analysis of the data: this was a difference between groups in the number of false detection, the experienced group yielding a significantly larger number of commission errors. This difference may represent a tendency for experienced observers to attach more meaning to observed changes of all kinds, including irrelevant ones.

Only one type of target was introduced into the photography in Experiment III. Although the search for a single type of target is not unrealistic in tactical operations, it imposes certain limitations on the interpretation of the data secured in the laboratory investigation of the two display methods. Specifically, the stimulus conditions permitted no distinction between the detection of a target change and its identification. If the observer saw an antiaircraft battery and reported it, the response was recorded as a correct detection. In the side-by-side display condition, the observer could have decided, after several comparisons of the two members of each pair, that no comparison was necessary, that the detection of an emplacement was sufficient without checking the second coverage to determine whether it was also present there. Any battery detected may have been assumed by the subject to have always been either added or removed. This situation would tend to favor the side-by-side method over that which obtained in previous experiments, where a change might be one of size or position and where a variety of targets was included. Moreover, the targets were relatively small in area and typically low in contrast with the background, as can be seen in Figure 34. The advantage that the apparent-motion method might have retained over the side-by-side display may have been lost because of this. Figure 14(A), in the "Results" section of Experiment I, shows that detection scores for the two display methods become less differentiated at the lower contrast levels.

In addition to nontarget man-made changes, there were many others involving sun angle, overall brightness and contrast, seasonal variations, and variations in the quality of the original photography. These occur, of course, in operational photography; but the unique sample used in Experiment III does not permit any evaluation of this source of variability. The possibility exists that the particular sample used was not representative of the population.

The foregoing is not an attempt to "explain away" the empirical results, but rather represents a necessary part of the critical evaluation of any piece of research. It is included here in the belief that no report is complete that does not bring the experimenter's intimate knowledge of research to bear on its criticism. The limitations listed are the usual ones associated with experimentation of necessarily limited scope; they are useful for the design of better subsequent research.

GENERAL CONCLUSIONS

The three experiments completed under this contract have contributed a substantial amount of new data on change detection from comparative-cover aerial photography. However, there are certain limitations that affect the interexperiment comparisons and generalizations of conditions deviating from those under which the data were obtained. The major restrictions stem from two primary sources: (1) the characterisics of the stimulus material, and (2) the task requirements.

A very serious difficulty, apparently inherent to this area of investigation, is that of obtaining reconnaissance photography that (1) allows precise control over those variables under investigation while holding all others constant, and (2) is representative of operational imagery to the extent that the data are maximally and immediately applicable. The research reported here is no less subject to these difficulties; although, among the three studies, various degrees of control over pictorial content and representativeness are included. A brief review of the major characteristics and differences in the stimulus material employed in the three experiments follows.

Experiment I — This material can be classified as "Homogeneous Noise — Heterogeneous Targets." The homogenity in noise results from the procedure involved in obtaining the comparative pairs. Since comparative pairs were obtained from successive photographs taken during the same reconnaissance mission, visual noise (irrelevant changes) was restricted to one type. The homogeneity of visual noise stems almost exclusively from the difference in "taking" angle associated with an invariant time base. The heterogeneity of targets was achieved by systematically introducing a wide variety of target objects and changes of known number and types.

Experiment II — The stimulus material used in this experiment can be classified as "Heterogeneous Noise — Heterogeneous Targets." The large amount and variety of noise arose from the inclusion of photography representing wide and variable time bases, without controlling the time of day, season of the year, atmospheric conditions, photographic equipment, or position of the reconnaissance vehicle. Since changes, both relevant and irrelevant, were numerous and "ground truth" was not known, a variety of target classes was specified for detection and a group concensus criterion was employed in the evaluation. A small proportion of artistically introduced targets were also included to provide data for evaluating this procedure to establish "ground truth" for experimental imagery.

Experiment III — The material involved in this study is classified as "Heterogeneous Noise — Homogeneous Targets." This imagery, procured locally, was originally obtained for real-estate evaluation. Thus, time base, time of day, camera equipment, and spatial location of the aircraft were "controlled."

Foliage and ground-cover changes associated with seasonal differences and man-made changes not of military significance contributed a moderate amount of heterogeneous visual noise. The specific targets (antiaircraft artillery batteries) designated for detection were artistically introduced on the photography.

The task requirements also varied from one study to the next, thereby further complicating the interexperiment comparisons. The nature of the task was most often predicated upon the number and specific characteristics of the stimulus material available. In Experiment I the problem confronting the observer was to report each change detected and to identify each detected change by type and class of object. Since reporting all of the large number of changes represented on the extended time-base imagery of Experiment II would have constituted a prohibitively lengthy assignment, a specific target class (or a few classes) was designated as "relevant" for each comparative pair. Generally, these target classes were gross (i.e., warehouses, roads, harbor activity, etc.), and each photograph contained several examples of each specified class. In Experiment III only one specific and highly distinctive target was being sought, and the observers were thoroughly familiarized with the appearance of this particular target prior to the search.

The significant findings relating to each of the independent variables under investigation are summarized by each dependent variable in Table XXIII. Only two of these variables are common to all three experiments — display methods and experience levels. Of the eleven comparisons made between the side-by-side and apparent-motion display methods, four revealed significantly superior performance with the apparent-motion display, one revealed a significant difference favoring the side-by-side display, and performance scores for the remainder of the comparisons were essentially comparable with either display method. Prior training or experience in photointerpretation did not appear to facilitate information-extraction performance since, of the eleven comparisons made between groups, only two differences were significant, and both of these favored the non-photointerpreters.

The remaining independent variables listed in Table XXIII — contrast, scale, image quality, background, and time base — were treated in only a single experiment and thus should be interpreted in light of the conditions existing during the data collection. There does, however, appear to be sufficient evidence to demonstrate that as imagery is impoverished, either by reducing contrast or imposing blur, the proportion of targets detected will diminish. Photographic scale and background complexity, although significantly affecting detection times, are not unambiguous in their relationship to total performance. Performance differences attributable to the time base systematically investigated in Experiment III were not demonstrable.

Table XXIII SUMMARY TABLE OF SIGNIFICANT RESULTS FROM EXPERIMENTS I, II, AND III

INDEPENDENT VARIABLES

DEPENDENT MEASURES	EXPERIMENT NUMBER	DISPLAY METHODS	EXPERIENCE LEVEL	CONTRAST LEVEL	PHOTO SCALE	IMAGE QUALITY	BACKGROUND COMPLEXITY	TIME BASE
Correct Detections	I (1)	AM *	NS	HI	--	--	--	--
	II	NS AM (6)	NS	--	LS LS (6)	HI HI (6)	NS	--
	III	NS	NS	--	--	--	--	NS
Detection Time	I	AM	NS	NS	--	--	--	--
	II (2)	AM	NS	--	LS (3)	NS	RS (5)	--
	III	NS	NS	--	--	--	--	NS
Commission Errors	I	SS	NS	LO	--	--	--	--
	II	NS	NS	--	LS (4)	NS	NS	--
	III	NS	N	--	--	--	--	NS
Identifications	I	AM	NS	HI	--	--	--	--
Identification Time	I	NS	N	NS	--	--	--	--

* Circled entries are significant at or beyond the 5 percent probability level. Significant entries are coded according to the favored condition.

(1) Significant interaction exists between display methods and contrast levels.

(2) Significant interaction exists between backgrounds and scale for non-P.I. Group only.

(3) Large-scale imagery significantly favorable for P.I. Group only.

(4) Large-scale imagery significantly favorable for P.I. Group only.

(5) Rural-suburban backgrounds significantly favorable for non-P.I. Group only.

(6) Significant in second analysis where backgrounds were pooled (see page ______).

KEY:

AM	Apparent-Motion Display	HI	High (Quality or Contrast)	RS	Rural and Suburban
SS	Side-by-Side Display	LO	Low (Quality or Contrast)	NS	Not Significant
N	Non-P.I. Group	LS	Large Scale (1:10,000)	--	Not Investigated

RECOMMENDATIONS

In ten of the eleven comparisons of display methods shown in Table XXIII, performance with the apparent-motion presentation was equal to or better than that obtained with the side-by-side display. There is also substantial information indicating that with certain types of imagery significantly more target changes can be detected and classified in less time with the apparent-motion display method. Additional research is needed to permit a more precise specification of the types of reconnaissance imagery for which the apparent-motion method is most appropriate. From the data reported in this document and that obtained prior to this program, it appears that the advantages of the apparent-motion display method diminish as irrelevant random visual noise increases. However, there is evidence that such a display system can tolerate a considerable amount of systematic noise without an appreciable loss in effectiveness. Future research in this area should attempt to use samples of operational reconnaissance photography obtained specifically for comparative cover analyses. Mission requirements could then be established for the acquisition of imagery that is within the tolerance limits of such a display system. Future investigation should also include an assessment of the use of the apparent-motion display for inspecting imagery other than vertical photography. For example, is the display system amenable to comparisons of oblique photographs, of radar, or of infrared imagery? Can multisensor imagery be combined in such a display system to further facilitate information extraction?

The continued investigation of imaging characteristics (i.e., contrast, resolution, scale, etc.) intrinsic to various sensing systems and the establishment of trade-off functions between these factors as predictors of performance are highly recommended.

The display apparatus employed in the present series of experiments can best be described as a second-stage prototype. Based on several hundred hours of usage, the following recommendations for the construction of an improved model are offered:

1) The inclusion of a manual or automatic three-directional staging unit for aligning the two imagery samples being compared;

2) The design and incorporation of an optical-mechanical rectification and sizing component;

3) The addition of precision controls for varying alternation rate and independent channel illumination;

4) The provision for front lighting to view opaque materials as well as to transilluminate positive and negative transparencies;

5) The expansion of the material-handling capability to include various format sizes and continuous strip imagery.

These changes would significantly increase the versatility of the display system and would permit the investigation of important variables currently beyond the capabilities of the existing equipment.

There are also numerous procedural variables (e.g., the selection and training of observers, the amount of preintelligence provided, the task duration and work load, and the specific task requirements) that must be investigated for a complete evaluation of the apparent-motion display system as a technique for enhancing the speed, accuracy, and completeness of target-change detection performance.

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APPENDIX I

TRAINING AND EXPERIENCE OF PHOTOINTERPRETERS USED IN EXPERIMENTS I, II, AND III

Subject	Training and Experience
TLA	Completed Air Force photointerpretation course, 14 weeks, taken in Orlando, Florida, in 1944. Served with Air Force Photo Mapping Squadron prior to 1946; worked at the Aero Charting Service in St. Louis for 2 months in 1950; served 2.5 years with the 67th, 363rd, and 2nd Reconnaissance Technical Squadrons from 1950 to 1953, where he did photointerpretation work in both Korea and the U.S. Was in charge of a Flak Interpretation Unit in Korea and did radar strike photo grading on practice missions and USAF bombing competitions (1952). Has also had experience in industrial target analysis, bomb-damage assessment on foreign targets, and in the reduction of map reference files to color microfilm for mobility at Barksdale AFB.
KAA	Completed the 6-week photinterpretation course in conjunction with the 17-week Officer's Intelligence Course conducted by the Army at Ft. Riley, Kansas, in 1949. Utilized this training for 3 years as Battalion Intelligence Officer, Intelligence and Reconnaissance Platoon Leader, and Regimental Intelligence Officer. Has had experience in all phases of conventional photointerpretation methods and procedures and for updating maps for tactical missions.
TAB	Received training in aerial photography and mapping at Colorado A&M College (14-week R.O.T.C. course) and with the Soil Conservation Service (6 weeks plus field training). Worked 3 years with the Soil Conservation Service in Colorado where, working entirely from aerial photographs, he was involved with the determination and measurement of soil conservation practices.
RGC	Completed 48 weeks of training at University of Washington from 1954 to 1956 in forestry-oriented photointerpretation. Courses included photogrammetry, timber cruising, and road location. Experience includes both private business and U.S. Forest Service work, which utilized photointerpretation for forest inventory, logging settings, road locations, fire control, and pest control.
GED	Completed 6 weeks course, Photointerpretation for Air-Dropping Cargo, at Olmstead AFB in 1952. Thereafter worked for 6 years for USAF relating aerial photographs to air drops.
CHF	Received U.S. Army topographical training courses of unspecified extent. From September 1939 to March 1942 duties as member of the photogrammetry company of the 29th Engineering Topographical Battalion included use of photo-mapping equipment. From June 1942 to March 1944 supervised similar work in 30th and 660th Engineering Topographic Battalions.

Subject	Training and Experience
AMG	Completed 6-month photo mapping and interpretation course at Fort Belvoir in 1952. Received further job training with 111th Reconnaissance Technical Squadron, Fairchild AFB. Balance of USAF experience consisted of radar and photointerpretation, mapping, and three-dimensional model derivation utilizing B36 Tri-met film.
DFH	13 weeks of schooling at Fort Holabird, followed by 5 years of active reserve service in Detachment 11, 6262nd ARSU with annual 2-week school and field sessions. Training emphasis on identification and analysis of industrial areas.
HJH	Completed 28-week course in aerial geology at Portland State College (1955). Then worked for 1.5 years for the State of Oregon Department of Geology, evaluating aerial photographs for geologic content, with particular emphasis on glacial activity.
FSH	Received 20 weeks of aerial photography at Santa Ana, California, in 1942. Had 8 weeks of bomb interpretation while in the 8th AF in England in 1943; duty: inspection of bomb damage inflicted on Germany. From 1953 to 1960 worked in an Air Force reserve squadron as a photointerpreter, finding targets and assessing damage after training strikes.
RJH	Organized and taught photo-mapping course in civil engineering at Oregon State University for 8 years. Completed a course of photo mapping while in the U.S. Army. Has had training in Multiplex and stereo-comparagraph.
GLI	Completed a 4-month photointerpretation course at Ft. Sill while in the U.S. Army in 1951. Had short training periods on target evaluation from photos taken over 1951-1953. While in an artillery unit, was a photointerpreter for purposes of selecting military targets.
RTK	Completed 3-month course in interpretation and use of aerial photographs at the University of Colorado in 1950. Was an aerial photographer in the Army and Air Force. Work included compilation of navigational charts from aerial photographs and photointerpretation.
RWO	Completed 12-week photogrammetry course at University of Washington in 1951. Has used aerial photos over the past 10 years for interpretation purposes in timber appraisal and woods survey. Has worked with topographical mapping using stereo photos in conjunction with ground control for contour mapping.

Subject	Training and Experience
HS	Completed 2-month photointerpreter course at Camp Ritchie, Md., in 1942 and 6-month photointerpreter course in London in 1943. Was a photointerpreter instructor at Camp Ritchie for 4 months and had 18 months' experience in World War II. The interpretation consisted in planning invasions, evaluations of enemy installations, bomb-damage assessment for artillery, and air strikes. In Korea, was an interpretation officer for 16 months.
AJP	Completed photointerpretation course at Ft. Davis and Ft. Bragg, for 4 weeks. Was an instructor in Basic Training Course (AA and AT) for the 13th Airborne Division in 1944-1945.
SHP	Received 6 months' training in topographical surveying at Ft. Belvoir while in the Army in 1954. He had experience in photography work when in the army and when employed with Aero Service in Philadelphia.
EAR	Aerial photos utilized in courses and thesis (M.S.) in geology. Has had 3 years of interpretation of geological features, including stereoscopic and photogrammetric methods.
EAS	Received formal photointerpretation training in France in 1944 while in the U.S. Army. Used photos for briefings for airborne landings in identification of terrain features and enemy positions.
PLS	No formal training; however, extensive experience in all phases of aerial photography as a member of Ohio and Maryland National Guard Photo Sections. Emphasis on scaling and map-making, with considerable work on oblique aerial photos.
DCO'M	Was aerial photographer for the Northern Pacific Railroad. Worked on land photos with emphasis on timber and right-of-ways. Some work was done with infrared photos. Developed and interpreted photos using stereo apparatus.

APPENDIX II

CHARACTERISTICS OF TARGET CHANGES IN AERIAL PHOTOGRAPHS USED AS STIMULI IN EXPERIMENT I

CHARACTERISTICS OF TARGET CHANGES

Slide No.	Number of Targets	Type of Target	Size of Target (Inches)	Type of Change	Percent Contrast	Contrast*	Position
1	No Change						
2	1	House	0.3 x 0.3	Number —add	50 P	3/5	20
3	2	Ship	0.10 x 0.60	Number — remove	67 P	4/7	10
		Oil tank	0.26 x 0.26	Number — remove	120 P	3/7	22
4	3	House	0.15 x 0.40	Number — add	30 N	3/5	11
		Barn	0.20 x 0.35	Number — add	61 P	2/6	9
		Tree cluster	0.24 x 0.60	Number — add	36 P	3/5	13
5	No Change						
6	1	Ship under construction	0.16 x 0.80	Complete bow	81 P	1/7	3
7	2	Building	0.30 x 0.44	Decrease 0.10 x 0.14 in.	80 N	10/6	14
		Shipping crates	0.18 x 0.30	Add crates to area to fill 0.09 x 0.15-in. space	23 P	1/6	11
8	3	Tree cluster	0.25 x 0.55	Decrease from two sides 0.1 in.	86 N	8/2	7
		Building	0.35 x 0.35	Decrease from two sides 0.1 in.	71 N	6/3	26
		Open space	0.14 x 0.18	Increase by 0.05 x 0.10 in.	67 N	7/3	29

* See end of table for clarification of contrast.

CHARACTERISTICS OF TARGET CHANGES (Continued)

Slide No.	Number of Targets	Type of Target	Size of Target (Inches)	Type of Change	Percent Contrast	Contrast*	Position
9	No change						
10	1	Tank cluster	0.23 x 0.35	Move vertical down 0.11 in.	29 P	1/3	24
11	2	Building	0.20 x 0.22	Move horizontal left 0.14 in.	34 N	4/1	20
		Building	0.20 x 0.30	Move vertical down 0.1 in.	34 N	1/5	11
12	3	Open space and tower	0.38 x 0.44	Move horizontal left 0.15 in.	20 P	2/7	14
		Apartment house	0.10 x 0.42	Move horizontal left 0.10 in.	30 P	2/5	19
		Two rows of automobiles	0.22 x 0.34	Move vertical down 0.12 in.	65 P	1/6	35
13	No change						
14	1	Add trees to space	0.30 x 0.30	Number — add	22 N	6/4	17
15	2	Tank cluster	0.20 x 0.53	Number — subtract	15 P	1/6	5
		Add building to space	0.30 x 0.13	Number — add	11 N	4/2	23
16	3	Ship	0.50 x 0.20	Number — add	70 P	1/4	25
		Building	0.30 x 0.30	Number — add	19 P	3/5	1
		Building	0.40 x 0.20	Number — add	164 P	2/4	15

* See end of table for clarification of contrast.

CHARACTERISTICS OF TARGET CHANGES (Continued)

Slide No.	Number of Targets	Type of Target	Size of Target (Inches)	Type of Change	Percent Contrast	Contrast*	Position
17	No change						
18	1	Three rows of small oil tanks	0.30 x 0.60	Complete two rows 0.40 x 0.12 in.	338 P	1/7	10
19	2	Tank cluster	0.40 x 0.52	Decrease to 0.15 x 0.40 in.	65 N	1/3	2
		Building	0.15 x 0.53	Decrease by 0.07 in.	76 P	12/4	30
20	3	Building	0.26 x 0.42	Increase size 0.07 x 0.11 in.	78 N	10/5	14
		Building	0.20 x 0.30	Increase size on one side 0.1 in.	49 N	7/1	22
		Space	0.34 x 0.44	Increase size on one side 0.1 in.	418 P	1/10	34
21	No change						
22	1	Stack of crates	0.20 x 0.46	Rotate 0.1 in.	88 N	12/1	21
23	2	Building	0.20 x 0.30	Move vertical up 0.1 in.	84 N	10/2	25
		Building	0.26 x 0.36	Rotate 0.1 in.	55 N	10/4	33
24	3	Tree cluster	0.24 x 0.24	Move vertical up 0.12 in.	65 N	10/4	8
		Building	0.40 x 0.38	Move horizontal right 0.2 in.	63 P	5/8	27
		Building	0.20 x 0.33	Rotate out 0.2 in.	52 P	1/7	22

*See end of table for clarification of contrast.

CHARACTERISTICS OF TARGET CHANGES (Continued)

Slide No.	Number of Targets	Type of Target	Size of Target (Inches)	Type of Change	Percent Contrast	Contrast*	Position
25	No change						
26	1	Add building to space	0.50 x 0.20	Number — add	14 N	4/9	22
27	2	Building	0.16 x 0.45	Number — add	9 N	4/6	1
		Building	0.25 x 0.50	Number — subtract	9 N	4/8	6
28	3	Building	0.20 x 0.40	Number — add	63 N	2/4	32
		Building	0.15 x 0.30	Number — add	45 N	8/5	3
		Building	0.15 x 0.35	Number — add	36 N	6/3	16
29	No change						
30	1	Building	0.24 x 0.40	Decrease to 0.12 x 0.20 in.	54 N	8/5	28
31	2	Circular space	0.2 (dia)	Increase diameter by 0.1 in.	307 P	1/6	25
		Building	0.12 x 0.30	Increase on two sides 0.06 x 0.12 in.	69 N	11/4	29
32	3	House	0.20 x 0.28	Increase by 0.10 x 0.14 in.	67 N	5/8	14
		Building	0.20 x 0.30	Increase on one side 0.15 in.	73 N	7/4	25
		Tree cluster	0.50 x 0.15	Add row of trees 0.50 x 0.15 in.	35 N	8/6	17

*See end of table for clarification of contrast.

CHARACTERISTICS OF TARGET CHANGES (Continued)

Slide No.	Number of Targets	Type of Target	Size of Target (Inches)	Type of Change	Percent Contrast	Contrast*	Position
33	No change						
34	1	Tree cluster	0.20 x 0.30	Move horizontal right 0.1 in.	85 N	9/6	16
35	2	Building	0.24 x 0.36	Move horizontal left 0.12 in.	15 N	6/8	13
		Airplane hangar	0.30 x 0.46	Move vertical down 0.16 in.	64 P	2/6	2
36	3	Barge	0.16 x 0.28	Move vertically up 0.15 in.	114 P	2/4	12
		Boat	0.14 x 0.98	Move horizontally left 0.10 in.	43 N	1/4	8
		Building	0.28 x 0.40	Move horizontally left 0.15 in.	36 N	1/3	35

*Contrast based on Eastman Kodak gray scale; No. 1 is lightest and No. 12 is darkest, as matched on original prints.

Scale	Density Value	Relative Reflectance (%)
1	0	100
2	0.20	63.0
3	0.36	43.6
4	0.45	35.4
5	0.57	27.0
6	0.72	19.1
7	0.88	13.0
8	1.05	8.9
9	1.20	6.3
10	1.33	4.7
11	1.48	3.3
12	1.67	2.1

$$\% \text{ Contrast } \frac{B_b - B_t}{B_b} \times 100$$

where B_b = apparent background luminance
B_t = apparent target luminance

Data from reading made on positive transparencies with a Kodak densitometer; one reading on the target and four background readings, one on each side and immediately adjacent to the target, the latter averaged, and all densities transformed into percent transmission for calculation of percent contrast.

APPENDIX III

AERIAL PHOTOGRAPHS REPRESENTATIVE OF COMPARATIVE COVERAGES USED IN EXPERIMENT II

AERIAL PHOTOGRAPHS REPRESENTATIVE OF COMPARATIVE COVERAGE

TYPE	NAME	LOCATION†	COVERAGE	PHOTO DESIGNATION AND NEGATIVE NO.	SCALE (9x9 Print)	QUALITY	AGENCY*	USAGE^{x}
Naval Shipyard	Portsmouth, N. H.	1	A, 1943	1st sq. 890 R.M 11 V 89-93	1:24,000	good	AF	
			B, 1946	Mass by roll MB 11 V 936-938	1:21,000	good	AF	x xx
			C, 1952	Rockingham Co. NH-DQW 10-K V 23-24	1:24,000	good	AG	x xx
Naval Shipyard	Naval Air Station; Norfolk, Va.	2	A, early	Proj Norfolk Strip 13 V 14-19 Proj Norfolk Strip 14 V 16-18	1:20,000	good	AF	
			B, 1953	Proj 47-5 R426 Strip 12 VV 16-19 Proj 47-3 R425 Strip 10 VV 12-16 Proj 47-3 R425 Strip 11 VV 10-14	1:20,000	good	AF	
			C, 1957	USAF ACRPL 59-1 V 48-56 59-65 67-75 79-88 88-94	1:10,000	good	AF	
Naval Shipyard	Brooklyn, N. Y.	3	A, 1942	N.Y. HBR Roll 37 Strip 1 V 13-15 N.Y. HBR Roll 37 Strip 2 V 66-68	1:17,000	good	AF	x xx xxx
			B, 1943	16 DPU-4M-716-1 V 166-168 188-191 237-240	1:10,000	good	AF	
			C, 1954	1355 M&C sq. 54-AM 10M 153 V 50-52 61-69	1:21,000	good	AF	x xx xxx

* Agency Key: AF = Air Force; AG = Dept of Agriculture; GS = Geological Survey or Coast and Geodetic Survey.

† Location Key: See attached map, this appendix.

x Used in 1:10,000 scale photographs.

xx Used in 1:20,000 scale photographs.

xxx Used in 1:40,000 scale photographs.

AERIAL PHOTOGRAPHS REPRESENTATIVE OF COMPARATIVE COVERAGE

TYPE	NAME	LOCATION+	COVERAGE	PHOTO DESIGNATION AND NEGATIVE NO.	SCALE (9x9 Print)	QUALITY	AGENCY*	USAGE^x^
Naval Amphib. Base	Little Creek, Va.	4	A_1, 1942	Proj 47-2 R424 Strip 7 VVM 10-12	1:20,000	good	AF	
			A_2	Proj 47-4 R426 Strip 8 VV 10-13	1:20,000	good	AF	
			B, 1943	Proj 183 R249 VV 1-2	1:15,000	fair	AF	
			C, 1951	USAF/ACRPL 59-1 V 32-39 41-46	1:10,000	good	AF	
			D, 1959	Proj 16/3-211 Roll 88 VV 6	1:14,000	fair	AF	
Army Depot	Ft. Knox, Ky.	5	A, 1946	311RW-11PTU-6PI39- 395-898 V 8-11 V 31-34	1:25,000	fair	AF	
			B, 1947	311RW-11PTU-586 V 1-5 Proj 75-119 19-23	1:20,000	good	AF	xx xxx
			C, 1956	16PDU Proj 395 R2 V 60-66 80-86	1:20,000	fair	AF	xx xxx
			D, 1957	118 TRW-105 PI2976 6" V 7-11 16-21 24-28	1:15,000	good	AF	
Army Depot	Aberdeen Proving Grounds	6	A, 1943	Aberdeen, Md., Proj 184-16 PSR-105 V 8-11 V 31-34	1:20,000	good	AF	x xx xxx
			B, 1947	AMS-AS-M8 Proj 36 VV 738-742 785-791 817-824	1:25,000	good	AF	x xx xxx
			C, 1957	Harford Co., Md., ANK 3T V 20-25 33-38 74-80 95-100	1:18,000	good	AG	
Army Depot	Ft. Bragg, N.C.	7	A, 1941	Sym FB Strips 4-7 Strip 4 V 243-247 Strip 5 V 135-142 Strip 6 V 209-213 Strip 7 V 176-181	1:21,000	good	AF	x xx xxx
			B, 1943	NC Proj 28 R64 V 17-20 NC Proj 28 R63 V 138-140	1:35,000	poor	AF	x xx xxx
			C, 1955	1372 M&C -- 54 AM 19B-M294 V 42-47 61 146-151	1:21,000	fair	AF	xx xxx

AERIAL PHOTOGRAPHS REPRESENTATIVE OF COMPARATIVE COVERAGE

TYPE	NAME	LOCATION+	COVERAGE	PHOTO DESIGNATION AND NEGATIVE NO.	SCALE (9x9 Print)	QUALITY	AGENCY*	USAGE^x
Army Depot (Cont.)	Ft. Bragg, N.C.	7	C, 1957 (Cont.)	1372 M&C -- 54AM 19 B M 315 VV 475-481				
			D, 1958	16 TRS 823 Proj 61-58 VV 1-43	1:11,000	good	AF	
Army Depot	Ft. Eustis, Va.	8	A, 1947	Norfolk Mapping 47-1 R427 Strip 19 V 25-27 Norfolk Mapping 47-1 R427 Strip 20 V 27-29	1:20,000	fair	AF	x
			B, 1953	TAC 303 TRS 591 VV 97-102 59-60	1:20,000	good	AF	x xx
			C, 1955	Proj 55-AM-18-1372 Mac Sq. M296 VV 61-62 76-68	1:20,000	good	AF	x xx
Training Area	Ft. Warren, Wyo.	9	A, 1941	5 SRW SRT R1582 VV 78-82	1:20,000	fair	AF	
			B, 1951	Proj Ft. Warren, Wyo. VV 46-50 56-61 77-83	1:11,000	good	AF	xxx
			C, 1953	AMS Proj 126 R57 Strip 43 V 4921-4922	1:60,000	good	GS	xxx
			D, 1956	Laramie Co., Wyo. BBT 5R V 198-200	1:20,000	good	AG	xxx
			E, 1957	Wyoming 57S V 3330-3332	1:30,000	good	GS	xxx
Air Force Base	Lockbourne AFB, Ohio	10	A, 1942	Quad-9 A 765A VV 11-14 30-33	1:20,000	fair	AF	
			B, 1951	GS-XM-R-1 VV 19-21 42-45 79-81	1:30,000	good	GS	
			C, 1953	Lockheed Flt-35-32 Proj Pace SIY VV 30-32 113-115	1:80,000	fair	AF	
Air Force Base	Loring AFB, Maine	11	A, 1949	91 SRW-11 TRS 9 M110-393 V 81-85 106-112 124-129	1:12,000	good	AF	
			B, 1952	GS-UL-R-1 V 182-184 33-36 46-48	1:22,000	good	GS	

AERIAL PHOTOGRAPHS REPRESENTATIVE OF COMPARATIVE COVERAGE

TYPE	NAME	LOCATION+	COVERAGE	PHOTO DESIGNATION AND NEGATIVE NO.	SCALE (9x9 Print)	QUALITY	AGENCY*	USAGE×
Air Force Base (Cont.)	Loring AFB	11	C, 1953	28 SRW 28 RTS 648, 52 P 20C VT 26-29	1:66,000	poor	AF	
Air Force Base	Bunker Hill AFB, Ind.	12	A, 1948	Proj. GS HW R-2 V-74-77	1:40,000	fair	GS	xxx
			B, 1956	9 AF-17 TRS-17 557-98-56 V 137-139 158-160	1:46,000	fair	AF	
			C, 1957	Miami Co., Indiana BFM R2T V 101-103	1:20,000	good	AG	xxx
Defense System	Custer AFS Battlecreek, Mich.	13	A, 1955	Calhoun Co., Mich. BDF 2P V 107, 110, 111	1:40,000	good	AG	
			B, 1960	Calhoun Co., Mich. BDF 2AA V 64-66	1:40,000	good	AG	
Defense System	Montauk AFS, New York	14	A	Suffolk Co., N. Y. A5A 5D V 61-62	?	good	AG	
			B, 1947	Suffolk Co., N. Y. 58 W V 4929-4931	?	good	GS	
Industrial Facilities	Syracuse, N. Y.	15	A, 1951 -------	Onondago Co., N. Y. ARX 2H V 85-87	1:20,000	good	AG	
			B, 1947	Proj 55-AM-50-1372 Com Sq-M293 V 2123-2127 Proj 55-AM-50-1372 Com Sq-M163 V 1479-1482	1:40,000	good	AF	xxx xxx
Industrial Facilities	Norfolk, Va.	16	A, early	Proj 47-3 R425 Strip 11 V 5-7	1:21,000	fair	AF	xx
			B, 1958	Norfolk Co., Va. DGF 2V V 94-97 132-134	1:21,000	good	AG	xx
			C, 1959	USAF/ACRPL 59-1 Strip I V 103-108 Strip II V 109-111	1:11,000	good	AF	
Industrial Facilities	Newport News, Va.	17	A, 1943	Proj 47-5 R426 Strip 15 V 14-15	1:20,000	good	AF	x xx
			B, 1953	Warwick, Hampton, Newport News, Va. DWJ-4N V 82-83	1:20,000	good	AG	x xx

1	Portsmouth, N.H., Naval Shipyard
2	Norfolk, Va., Naval Air Station
3	Brooklyn, N. Y., Naval Shipyard
4	Little Creek, Va., Naval Amphib. Base
5	Ft. Knox, Ky., Army Depot
6	Aberdeen Proving Grounds, M.D., Army Depot
7	Ft. Bragg, N.C., Army Depot
8	Ft. Eustis, Va., Army Depot
9	Ft. Warren, Wyo., Training Area
10	Lockbourne AFB, Ohio
11	Loring AFB, Maine
12	Bunker Hill AFB, Indiana
13	Custer AFS, Michigan
14	Montaulk AFS, N. Y.
15	Syracuse, N. Y., Industrial Facilities
16	Norfolk, Va., Industrial Facilities
17	Newport News, Va., Industrial Facilities

Figure III-1 LOCATION KEY
Comparative Coverage Aerial Photographs

APPENDIX IV

METHOD OF DEGRADING IMAGERY WITH GAUSSIAN FILTER

APPENDIX IV

METHOD OF DEGRADING IMAGERY WITH GAUSSIAN FILTER

The technique that permitted the greatest manipulation of edge gradients without unwanted discontinuities was what the authors called the Fry technique. Dr. Glenn A. Fry has published a series of articles on the method and the advantages of its use (Fry, 1957 and 1961).

The technique uses a neutral density filter with a density distribution that is a normal gaussian or bell-shaped curve along any diameter. The modal density is in the center and decreases peripherally. The size of the filter is determined by the diameter of the entrance pupil of the lens with which it is used. The purpose of this diffusion filter is to modify the intensity of the light rays entering or leaving the objective lens. The less accurately refracted peripheral rays contribute proportionately more to the formation of the image with this filter. The resultant edge gradients are ogival in form, with the slope of the linear portion an inverse function of the degree of defocusing. The slope and shoulder of the gradient are smooth, as illustrated in the microdensitometer traces shown in Figure 15.

The apparatus used to make the gaussian filter is schematically represented in Figure IV-1. The light from the source is diffused in the condenser system to ensure homogeneous illuminance at the rotatable slit. The slit should be machined and have a length-to-width ratio of at least 10 to 1. Two exposures are used to produce the filter, with the slit rotated 90 degrees between the first and second exposure. The relative densities across the filter vary as a function of the distance between the slit and the diffuser, the type of film, and the development procedures.

The size of the gaussian filter is controlled by an adjustment of the distance between the diffuser and the film from which it is made. The average density of the filter varies with the length of the exposure, which is controlled by a shutter located at the projection lens.

This filter may be used either with the camera in making a negative of the picture in which blur is to be introduced or with a projector or enlarger. The latter use is illustrated in Figure IV-2. In either case the filter must be centered on the optical axis for the blur to be homogeneous.

The magnitude of the blur is produced by defocusing the projection equipment, and size may be maintained by increasing or decreasing the projection distance. Quantity of blur may be measured with an Air Force resolution chart, but must be checked by a microdensitometer to determine if false resolutions have occurred.

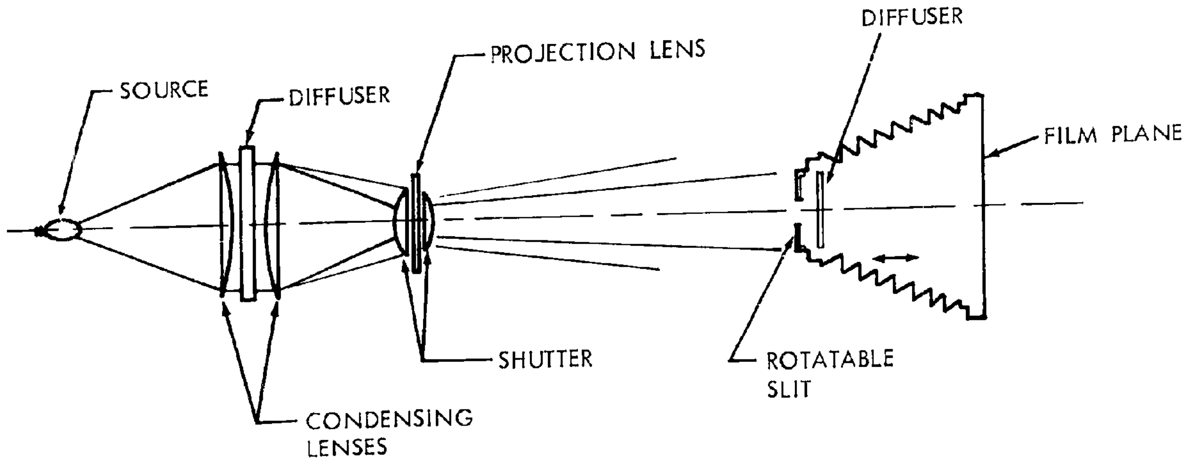

Figure IV-1 SCHEMATIC OF TECHNIQUE TO GENERATE DIFFUSING FILTER
Glenn A. Fry Technique

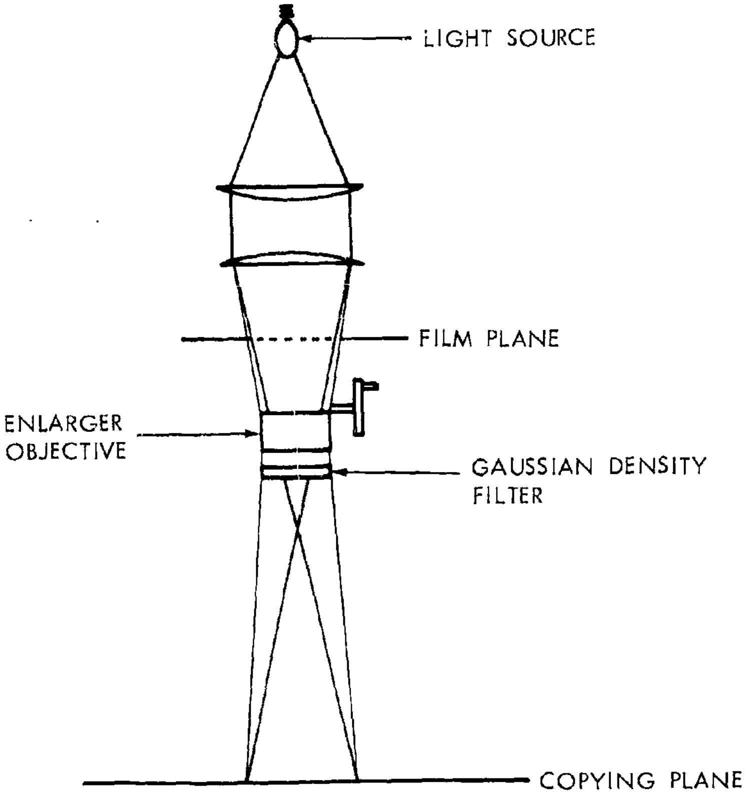

Figure IV-2 SCHEMATIC OF TECHNIQUE FOR USING GAUSSIAN FILTER IN GENERATING DIFFERENT BLUR QUANTITIES

APPENDIX V

EXPERIMENT I RAW DATA

EXPERIMENT I RAW DATA P.I. AND NON-P.I.

P.I. TOTAL TIME (SECONDS)

Subject	AM			SXS		
Number	20%	40%	60%	20%	40%	60%
1	1649	1120	1706	747	1686	1491
2	1219	1899	1800	1384	1362	1481
3	738	736	385	924	914	884
4	380	217	181	561	297	531
5	1184	691	739	1799	2603	2189
6	1411	1402	1459	1661	2306	2101
7	814	956	896	458	1068	788
8	1104	1153	1241	1376	1050	1703
9	580	540	602	1024	891	893
10	1069	720	1120	1865	1973	770
11	614	1029	974	1185	949	622
12	490	546	576	604	634	590
Total	11252	11009	11679	13588	15733	14043

NON-P.I. TOTAL TIME (SECONDS)

AM			SXS		
20%	40%	60%	20%	40%	60%
701	1366	905	1164	1098	1536
1178	1713	1901	1317	2749	1875
676	773	814	1326	1087	1286
630	560	957	1568	2078	1616
842	1032	1029	1736	1471	1124
832	772	807	803	1177	1020
890	1244	1218	1302	1080	1326
879	957	1464	893	1278	1012
615	1049	935	290	823	606
539	619	782	646	716	808
751	1170	551	988	1090	992
1518	1770	895	1821	1633	1857
10051	13025	12258	13854	16280	15058

P.I. MEAN TIME (SECONDS)
IN CORRECT IDENTIFICATIONS

Subject	AM			SXS		
Number	20%	40%	60%	20%	40%	60%
1	-	14	15	-	-	-
2	6	9	7	5	4	70
3	12	12	8	-	7	8
4	-	2	-	8	-	12
5	10	7	6	-	7	3
6	26	20	26	25	21	29
7	8	10	4	-	-	10
8	27	14	13	51	8	8
9	46	6	4	-	6	24
10	8	6	8	8	6	8
11	-	8	23	-	22	28
12	4	13	10	30	-	8
Total	147	121	124	127	81	148

NON-P.I. MEAN TIME (SECONDS)
IN CORRECT IDENTIFICATIONS

AM			SXS		
20%	40%	60%	20%	40%	60%
5	8	11	22	8	17
8	9	10	-	26	6
4	9	4	-	3	5
8	9	5	-	8	15
11	14	11	22	23	6
4	17	13	-	7	-
-	4	18	2	-	6
-	-	5	-	4	10
-	17	9	-	10	8
-	13	14	-	12	-
-	3	9	-	2	2
12	10	6	10	7	10
52	113	115	56	110	85

P.I. MEAN TIME (SECONDS)
CORRECT DETECTION

Subject	AM			SXS		
Number	20%	40%	60%	20%	40%	60%
1	-	70	129	-	-	-
2	73	109	80	180	212	82
3	98	46	23	-	59	95
4	-	14	6	66	-	70
5	66	11	28	-	68	131
6	116	42	77	76	113	138
7	63	39	58	-	-	25
8	60	39	56	165	55	182
9	35	23	50	-	103	22
10	93	29	92	130	123	28
11	-	42	49	-	37	11
12	106	49	33	65	-	58
Total	710	513	681	682	770	843

NON-P.I. MEAN TIME (SECONDS)
CORRECT DETECTIONS

AM			SXS		
20%	40%	60%	20%	40%	60%
71	87	68	80	111	135
51	50	96	201	226	183
48	37	46	-	42	106
45	56	61	-	309	130
47	45	99	47	117	12
79	43	45	-	116	137
11	110	98	184	158	84
136	106	67	-	40	54
-	61	66	-	57	3
-	21	72	61	12	-
-	80	28	-	68	79
96	86	19	148	48	125
594	782	765	721	1304	1053

EXPERIMENT I RAW DATA P.I. AND NON-P.I.

TOTAL POSSIBLE CORRECT

P.I.

Subject Number	AM			SXS		
	20%	40%	60%	20%	40%	60%
1	8	8	11	9	9	9
2	8	11	8	9	9	9
3	8	8	11	9	9	9
4	11	8	8	9	9	9
5	8	11	8	9	9	9
6	11	8	8	9	9	9
7	9	9	9	8	8	11
8	9	9	9	8	11	8
9	9	9	9	8	8	11
10	9	9	9	11	8	8
11	9	9	9	8	11	8
12	9	9	9	11	8	8
Total	108	108	108	108	108	108

NON-P.I.

AM			SXS		
20%	40%	60%	20%	40%	60%
8	8	11	9	9	9
8	11	8	9	9	9
8	8	11	9	9	9
11	8	8	9	9	9
8	11	8	9	9	9
11	8	8	9	9	9
9	9	9	8	8	11
9	9	9	8	11	8
9	9	9	8	8	11
9	9	9	11	8	8
9	9	9	8	11	8
9	9	9	11	8	8
108	108	108	108	108	108

CORRECT IDENTIFICATIONS

P.I.

Subject Number	AM			SXS		
	20%	40%	60%	20%	40%	60%
1	0	2	3	0	0	0
2	1	6	5	1	1	3
3	1	4	2	0	3	1
4	0	1	0	1	0	1
5	4	2	6	0	1	1
6	2	6	6	1	3	4
7	2	1	2	0	0	1
8	2	2	6	1	3	3
9	1	4	4	0	2	3
10	1	3	5	3	2	2
11	0	3	6	0	2	1
12	1	2	5	1	0	2
Total	15	36	50	8	17	22

NON-P.I.

AM			SXS		
20%	40%	60%	20%	40%	60%
1	4	5	1	2	2
1	5	5	0	3	3
4	2	6	0	2	1
2	2	5	0	1	2
1	3	4	1	2	1
2	3	5	0	1	0
0	2	2	1	0	3
0	0	6	0	3	1
0	5	4	0	1	1
0	5	4	0	1	0
0	3	3	0	1	1
2	1	5	2	2	3
13	35	54	5	19	18

CORRECT DETECTIONS

P.I.

Subject Number	AM			SXS		
	20%	40%	60%	20%	40%	60%
1	0	4	4	0	0	0
2	1	7	5	1	1	4
3	2	4	2	0	3	1
4	0	1	1	2	0	1
5	4	2	6	0	1	2
6	2	6	6	1	3	4
7	3	1	4	0	0	1
8	2	3	6	1	3	3
9	1	4	4	0	2	3
10	3	4	5	3	2	2
11	0	5	7	0	2	1
12	1	2	7	1	0	2
Total	19	43	57	9	17	24

NON-P.I.

AM			SXS		
20%	40%	60%	20%	40%	60%
1	4	7	1	2	2
1	5	6	1	3	3
4	3	8	0	3	2
2	3	5	0	2	2
3	3	4	1	2	1
2	5	5	0	1	1
1	2	4	1	2	3
1	1	7	0	3	1
0	6	6	0	1	1
0	7	5	2	1	0
0	4	5	0	2	2
3	2	7	4	2	4
18	45	69	10	24	22

COMMISSION ERRORS

P.I.

Subject Number	AM			SXS		
	20%	40%	60%	20%	40%	60%
1	0	12	10	0	1	1
2	2	2	5	2	1	3
3	3	1	3	0	1	2
4	5	3	3	4	3	2
5	1	9	4	1	4	4
6	3	3	4	1	0	0
7	4	9	6	0	6	3
8	6	5	4	0	0	2
9	5	9	4	6	4	2
10	2	6	6	5	3	3
11	2	9	11	1	2	1
12	3	4	3	2	0	0
Total	36	72	63	22	25	23

NON P.I.

AM			SXS		
20%	40%	60%	20%	40%	60%
1	10	6	1	1	2
1	3	5	0	0	0
2	3	9	1	2	6
2	1	4	0	5	0
2	2	1	0	2	3
4	1	3	1	1	2
10	10	10	2	6	4
3	5	12	0	3	0
3	11	8	0	0	2
4	8	14	2	0	4
2	5	4	2	5	2
7	12	10	12	4	10
41	71	86	21	29	35

* Note: 6 photos per subject per session

APPENDIX VI

EXPERIMENT II RAW DATA

EXPERIMENT II PERCENT OF TARGETS DETECTED NON-P.I.

1:10,000

			AM			SXS		
	Picture No.	Total Changes	Blur 0	Blur 2	Blur 4	Blur 0	Blur 2	Blur 4
Industrial	1	4	50	25	25	100	25	50
	2	1	100	0	0	100	0	100
	3	6	67	50	50	67	50	50
	4	4	75	75	50	100	100	50
	5	4	100	75	25	50	25	50
	6	2	50	50	50	100	50	50
	Total	21	442	275	200	517	250	350

1:20,000

			AM			SXS		
	Picture No.	Total Changes	Blur 0	Blur 2	Blur 4	Blur 0	Blur 2	Blur 4
Industrial	1	2	50	50	50	100	50	50
	2	5	80	80	100	40	60	60
	3	8	88	50	88	62	50	62
	4	1	100	0	100	100	100	0
	5	5	60	100	80	60	60	60
	6	4	100	50	50	75	50	25
	Total	25	478	330	468	437	370	257

1:40,000

			AM			SXS		
	Picture No.	Total Changes	Blur 0	Blur 2	Blur 4	Blur 0	Blur 2	Blur 4
Industrial	1	6	50	17	0	100	17	67
	2	4	25	50	0	100	50	25
	3	6	17	17	33	0	33	0
	4	3	33	33	100	67	67	0
	5	5	80	20	20	20	0	0
	6	5	0	60	0	20	0	40
	Total	29	205	197	153	307	167	132

1:10,000

			AM			SXS		
	Picture No.	Total Changes	Blur 0	Blur 2	Blur 4	Blur 0	Blur 2	Blur 4
Suburban	9	1	0	0	0	100	100	0
	10	1	100	0	0	0	100	0
	11	2	100	100	50	0	0	50
	12	3	33	100	33	67	0	67
	13	1	100	100	0	100	0	0
	14	1	100	100	100	100	100	100
	Total	9	433	400	183	367	300	217

1:20,000

			AM			SXS		
	Picture No.	Total Changes	Blur 0	Blur 2	Blur 4	Blur 0	Blur 2	Blur 4
Suburban	7	5	80	40	60	80	80	40
	8	4	50	50	50	0	25	75
	9	3	100	0	0	33	33	33
	10	3	100	100	67	67	67	67
	11	2	100	100	50	100	100	50
	12	7	86	42	42	57	42	28
	Total	24	516	332	269	337	347	293

1:40,000

			AM			SXS		
	Picture No.	Total Changes	Blur 0	Blur 2	Blur 4	Blur 0	Blur 2	Blur 4
Suburban	9	3	100	0	0	33	0	0
	10	10	20	10	20	20	30	0
	11	3	33	33	67	67	67	67
	12	4	50	25	0	25	25	0
	13	1	0	100	100	0	0	0
	14	6	33	67	33	17	0	33
	Total	27	236	235	220	162	122	100

1:10,000

			AM			SXS		
	Picture No.	Total Changes	Blur 0	Blur 2	Blur 4	Blur 0	Blur 2	Blur 4
Rural	17	4	25	75	50	50	50	0
	18	1	100	0	0	0	0	0
	19	None	100	100	100	100	100	100
	20	2	100	50	50	50	50	0
	21	2	100	100	50	0	100	100
	22	None	100	100	100	100	100	100
	Total	9	525	425	350	300	400	300

1:20,000

			AM			SXS		
	Picture No.	Total Changes	Blur 0	Blur 2	Blur 4	Blur 0	Blur 2	Blur 4
Rural	13	3	0	100	67	67	100	33
	14	0	100	100	100	100	100	100
	15	2	50	0	0	50	50	50
	16	2	100	100	50	50	50	50
	17	1	0	100	100	100	100	100
	18	1	100	100	100	100	100	0
	Total	9	350	500	417	467	500	333

1:40,000

			AM			SXS		
	Picture No.	Total Changes	Blur 0	Blur 2	Blur 4	Blur 0	Blur 2	Blur 4
Rural	17	4	25	25	0	50	0	50
	18	5	40	60	20	60	60	40
	19	4	0	25	25	0	75	0
	20	4	100	0	50	0	0	0
	21	6	33	33	0	17	17	33
	22	3	33	0	0	0	0	0
	Total	26	231	143	95	127	152	123

EXPERIMENT II NUMBER OF TARGETS DETECTED BY PICTURE NUMBER NON-P.I.

1:10, 000

Industrial

Picture No.	Changes	AM Blur 0	AM Blur 2	AM Blur 4	SXS Blur 0	SXS Blur 2	SXS Blur 4
1	4	2	1	1	4	1	2
2	1	1	0	0	1	0	1
3	6	4	3	3	4	3	3
4	4	3	3	2	4	4	2
5	4	4	3	1	2	1	2
6	2	1	1	1	2	1	1
Total	21	15	11	8	17	10	11

1:20, 000

Industrial

Picture No.	Changes	AM Blur 0	AM Blur 2	AM Blur 4	SXS Blur 0	SXS Blur 2	SXS Blur 4
1	2	1	1	1	2	1	1
2	5	4	4	5	2	3	3
3	8	7	4	7	5	4	5
4	1	1	0	1	1	1	0
5	5	3	5	4	3	3	3
6	4	4	2	2	3	2	1
Total	25	20	16	20	16	14	13

1:40, 000

Industrial

Picture No.	Changes	AM Blur 0	AM Blur 2	AM Blur 4	SXS Blur 0	SXS Blur 2	SXS Blur 4
1	6	3	1	0	6	1	4
2	4	1	2	0	4	2	1
3	6	1	1	2	0	2	0
4	3	1	1	3	2	2	0
5	5	4	1	1	1	0	0
6	5	0	3	0	1	0	2
Total	29	10	9	6	14	7	7

1:10, 000

Suburban

Picture No.	Changes	AM Blur 0	AM Blur 2	AM Blur 4	SXS Blur 0	SXS Blur 2	SXS Blur 4
9	1	0	0	0	1	1	0
10	1	1	0	0	0	1	0
11	2	2	2	1	0	0	1
12	3	1	3	1	2	0	2
13	1	1	1	0	1	0	0
14	1	1	1	1	1	1	1
Total	9	6	7	3	5	3	4

1:20, 000

Suburban

Picture No.	Changes	AM Blur 0	AM Blur 2	AM Blur 4	SXS Blur 0	SXS Blur 2	SXS Blur 4
7	5	4	2	3	4	4	2
8	4	2	2	2	0	1	3
9	3	3	0	0	1	1	1
10	3	3	3	2	2	2	2
11	2	2	2	1	2	2	1
12	7	6	3	3	4	3	2
Total	24	20	12	11	13	13	11

1:40, 000

Suburban

Picture No.	Changes	AM Blur 0	AM Blur 2	AM Blur 4	SXS Blur 0	SXS Blur 2	SXS Blur 4
9	3	3	0	0	1	0	0
10	10	2	1	2	2	3	0
11	3	1	1	2	2	2	2
12	4	2	1	0	1	1	0
13	1	0	1	1	0	0	0
14	6	2	4	2	1	0	2
Total	27	10	8	7	7	6	4

1:10, 000

Rural

Picture No.	Changes	AM Blur 0	AM Blur 2	AM Blur 4	SXS Blur 0	SXS Blur 2	SXS Blur 4
17	4	1	3	2	2	2	0
18	1	1	0	0	0	0	0
19	0	-	-	-	-	-	-
20	2	2	1	1	1	1	0
21	2	2	2	1	0	2	2
22	0	-	-	-	-	-	-
Total	9	6	6	4	3	5	2

1:20, 000

Rural

Picture No.	Changes	AM Blur 0	AM Blur 2	AM Blur 4	SXS Blur 0	SXS Blur 2	SXS Blur 4
13	3	0	3	2	2	3	1
14	0	-	-	-	-	-	-
15	2	1	0	0	1	1	1
16	2	2	2	1	1	1	1
17	1	0	1	1	1	1	1
18	1	1	1	1	1	1	0
Total	9	4	7	5	6	7	4

1:40, 000

Rural

Picture No.	Changes	AM Blur 0	AM Blur 2	AM Blur 4	SXS Blur 0	SXS Blur 2	SXS Blur 4
17	4	1	1	0	2	0	2
18	5	2	3	1	3	3	2
19	4	0	1	1	0	3	0
20	4	4	0	2	0	0	0
21	6	2	2	0	1	1	2
22	3	1	0	0	0	0	0
Total	26	10	7	4	6	7	6

EXPERIMENT II TOTAL TIME (SECONDS) ON PICTURES NON-P.I.

1:10,000

Industrial

Picture No.	Changes	AM Blur 0	AM Blur 2	AM Blur 4	SXS Blur 0	SXS Blur 2	SXS Blur 4
1	4	38	84	132	277	162	154
2	1	173	86	90	131	140	88
3	6	106	233	118	90	190	235
4	4	50	93	81	94	123	79
5	4	174	199	103	179	331	232
6	2	160	75	122	98	80	133
Total	21	756	770	646	869	1026	926

1:20,000

Industrial

Picture No.	Changes	AM Blur 0	AM Blur 2	AM Blur 4	SXS Blur 0	SXS Blur 2	SXS Blur 4
1	2	153	146	83	183	201	387
2	5	77	170	149	131	223	135
3	8	180	228	327	287	531	408
4	1	251	166	256	184	144	76
5	5	270	176	80	165	83	176
6	4	142	241	251	246	163	157
Total	25	1073	1127	1146	1196	1345	1339

1:40,000

Industrial

Picture No.	Changes	AM Blur 0	AM Blur 2	AM Blur 4	SXS Blur 0	SXS Blur 2	SXS Blur 4
1	6	100	143	222	155	188	288
2	4	363	51	138	361	312	195
3	6	202	354	166	162	263	216
4	3	146	116	151	89	186	187
5	5	212	169	210	219	39	361
6	5	123	118	59	238	103	77
Total	29	1146	951	946	1224	1091	1324

1:10,000

Suburban

Picture No.	Changes	AM Blur 0	AM Blur 2	AM Blur 4	SXS Blur 0	SXS Blur 2	SXS Blur 4
9	1	76	56	136	122	73	54
10	1	152	130	110	103	77	114
11	2	90	70	138	73	157	149
12	3	73	170	123	89	104	83
13	1	85	113	46	245	110	100
14	1	33	94	68	170	155	99
Total	9	564	633	621	907	681	599

1:20,000

Suburban

Picture No.	Changes	AM Blur 0	AM Blur 2	AM Blur 4	SXS Blur 0	SXS Blur 2	SXS Blur 4
7	5	185	160	57	197	168	290
8	4	142	155	64	248	262	155
9	3	172	137	205	112	281	247
10	3	198	98	260	133	134	104
11	2	99	111	101	109	125	104
12	7	126	293	162	211	96	113
Total	24	922	954	849	1010	1066	1013

1:40,000

Suburban

Picture No.	Changes	AM Blur 0	AM Blur 2	AM Blur 4	SXS Blur 0	SXS Blur 2	SXS Blur 4
9	3	87	203	114	161	137	272
10	10	315	60	165	204	341	106
11	3	147	346	79	281	333	134
12	4	117	164	188	165	152	256
13	1	248	95	223	244	42	137
14	6	235	212	186	225	204	54
Total	27	1149	1030	955	1280	1209	959

1:10,000

Rural

Picture No.	Changes	AM Blur 0	AM Blur 2	AM Blur 4	SXS Blur 0	SXS Blur 2	SXS Blur 4
17	4	122	90	131	306	203	137
18	1	176	112	69	92	60	147
19	0	90	70	70	92	115	136
20	2	116	68	66	97	151	54
21	2	77	22	83	128	55	183
22	0	130	50	52	77	70	133
Total	9	711	412	471	792	659	790

1:20,000

Rural

Picture No.	Changes	AM Blur 0	AM Blur 2	AM Blur 4	SXS Blur 0	SXS Blur 2	SXS Blur 4
13	3	213	152	94	310	167	174
14	0	68	58	95	116	59	108
15	2	128	99	81	129	232	163
16	2	216	94	290	41	136	82
17	1	127	165	111	130	51	75
18	1	54	145	65	217	58	68
Total	9	806	713	736	943	703	670

1:40,000

Rural

Picture No.	Changes	AM Blur 0	AM Blur 2	AM Blur 4	SXS Blur 0	SXS Blur 2	SXS Blur 4
17	4	84	224	239	161	109	443
18	5	229	51	177	216	214	139
19	4	231	195	151	160	336	185
20	4	284	80	191	50	267	250
21	6	124	111	155	177	40	215
22	3	78	285	79	204	345	43
Total	26	1030	946	982	968	1311	275

Note: Photo's #7, 8, 15, 16, 23, 24, were presented to P.I.'s only.

EXPERIMENT II COMMISSION ERRORS NON-P.I.

1:10,000

Industrial

Picture	Changes	AM			SXS		
No.		Blur 0	Blur 2	Blur 4	Blur 0	Blur 2	Blur 4
1	4	0	0	0	0	1	0
2	1	1	0	1	1	0	0
3	6	1	0	0	2	1	1
4	4	0	1	0	0	0	0
5	4	0	6	0	0	1	2
6	2	0	0	1	1	4	4
Total	21	2	7	2	4	7	7

1:20,000

Industrial

Picture	Changes	AM			SXS		
No.		Blur 0	Blur 2	Blur 4	Blur 0	Blur 2	Blur 4
1	2	2	2	1	0	6	2
2	5	0	5	4	0	2	1
3	8	2	3	6	6	3	4
4	1	2	5	0	0	1	1
5	5	1	0	1	2	0	1
6	4	8	3	8	1	1	4
Total	25	15	18	20	9	13	13

1:40,000

Industrial

Picture	Changes	AM			SXS		
No.		Blur 0	Blur 2	Blur 4	Blur 0	Blur 2	Blur 4
1	6	0	0	0	0	0	3
2	4	1	0	4	4	4	1
3	6	0	1	2	2	3	2
4	3	4	0	4	2	0	2
5	5	13	1	2	2	3	3
6	5	0	3	0	0	1	0
Total	29	18	5	12	10	11	11

1:10,000

Suburban

Picture	Changes	AM			SXS		
No.		Blur 0	Blur 2	Blur 4	Blur 0	Blur 2	Blur 4
9	1	1	0	9	1	0	0
10	1	2	0	1	1	0	3
11	2	1	0	0	0	0	0
12	3	1	3	0	3	0	0
13	1	0	2	0	2	0	0
14	1	0	1	2	2	5	1
Total	9	5	6	12	9	5	4

1:20,000

Suburban

Picture	Changes	AM			SXS		
No.		Blur 0	Blur 2	Blur 4	Blur 0	Blur 2	Blur 4
7	5	6	3	1	3	4	1
8	4	1	4	6	2	5	7
9	3	1	1	2	0	0	1
10	3	4	2	0	0	1	1
11	2	1	1	3	0	0	1
12	7	3	2	0	0	2	1
Total	24	16	13	12	5	12	12

1:40,000

Suburban

Picture	Changes	AM			SXS		
No.		Blur 0	Blur 2	Blur 4	Blur 0	Blur 2	Blur 4
9	3	1	1	1	2	1	1
10	10	0	2	2	4	2	0
11	3	1	1	2	2	0	1
12	4	1	0	4	0	0	0
13	1	1	2	3	4	3	2
14	6	0	4	2	1	1	1
Total	27	4	10	14	13	7	5

1:10,000

Rural

Picture	Changes	AM			SXS		
No.		Blur 0	Blur 2	Blur 4	Blur 0	Blur 2	Blur 4
17	4	0	2	6	3	1	3
18	1	3	1	2	0	0	5
19	0	3	1	0	0	0	0
20	2	1	0	0	7	0	1
21	2	0	0	1	1	0	0
22	0	1	0	0	1	0	2
Total	9	8	4	9	12	1	11

1:20,000

Rural

Picture	Changes	AM			SXS		
No.		Blur 0	Blur 2	Blur 4	Blur 0	Blur 2	Blur 4
13	3	4	2	0	6	3	0
14	0	1	1	2	0	1	3
15	2	1	0	0	7	1	4
16	2	5	4	3	0	0	1
17	1	1	3	8	3	0	1
18	1	0	0	0	1	0	0
Total	9	12	10	13	17	5	9

1:40,000

Rural

Picture	Changes	AM			SXS		
No.		Blur 0	Blur 2	Blur 4	Blur 0	Blur 2	Blur 4
17	4	2	1	1	7	2	6
18	5	1	2	2	4	1	0
19	4	1	0	1	0	5	0
20	4	5	0	4	0	2	1
21	6	0	0	0	0	1	0
22	3	0	5	0	0	2	1
Total	26	9	8	8	11	13	8

EXPERIMENT II NUMBER OF TARGETS DETECTED BY SUBJECT NUMBER NON-P.I.

Industrial

1:10,000	AM			SXS		
Subject No.	Blur 0	Blur 2	Blur 4	Blur 0	Blur 2	Blur 4
1	2	3	1	1	4	1
2	1	3	1	4	3	2
3	4	3	1	4	1	1
4	3	1	0	4	1	2
5	4	1	3	2	0	2
6	1	0	2	2	1	3
Total	15	11	8	17	10	11

Industrial

1:20,000	AM			SXS		
Subject No.	Blur 0	Blur 2	Blur 4	Blur 0	Blur 2	Blur 4
7	1	4	7	1	3	1
8	1	5	2	2	3	5
9	4	4	1	3	2	0
10	3	2	1	2	4	1
11	7	1	5	3	1	3
12	4	0	4	5	1	3
Total	20	16	20	16	14	13

Industrial

1:40,000	AM			SXS		
Subject No.	Blur 0	Blur 2	Blur 4	Blur 0	Blur 2	Blur 4
13	3	2	2	2	0	2
14	1	1	0	6	2	0
15	1	1	0	1	0	0
16	4	3	3	4	2	4
17	1	1	0	1	2	0
18	0	1	1	0	1	1
Total	10	9	6	14	7	7

Suburban

1:10,000	AM			SXS		
Subject No.	Blur 0	Blur 2	Blur 4	Blur 0	Blur 2	Blur 4
1	0	2	0	0	0	1
2	1	3	1	1	0	0
3	2	1	0	2	1	0
4	1	1	0	0	0	0
5	1	0	1	1	1	2
6	1	0	1	1	1	1
Total	6	7	3	5	3	4

Suburban

1:20,000	AM			SXS		
Subject No.	Blur 0	Blur 2	Blur 4	Blur 0	Blur 2	Blur 4
7	4	2	0	2	2	2
8	3	2	3	4	1	1
9	2	0	3	2	3	2
10	2	3	2	0	1	2
11	3	2	2	4	2	1
12	6	3	1	1	4	3
Total	20	12	11	13	13	11

Suburban

1:40,000	AM			SXS		
Subject No.	Blur 0	Blur 2	Blur 4	Blur 0	Blur 2	Blur 4
13	3	1	2	1	0	2
14	2	1	2	1	3	2
15	2	1	0	0	0	0
16	0	4	0	2	2	0
17	1	0	2	1	1	0
18	2	1	1	2	0	0
Total	10	8	7	7	6	4

Rural

1:10,000	AM			SXS		
Subject No.	Blur 0	Blur 2	Blur 4	Blur 0	Blur 2	Blur 4
1	1	-	1	0	1	-
2	1	1	-	2	-	2
3	-	2	2	1	-	0
4	2	-	0	-	2	0
5	2	3	-	-	0	0
6	-	0	1	0	2	-
Total	6	6	4	3	5	2

Rural

1:20,000	AM			SXS		
Subject No.	Blur 0	Blur 2	Blur 4	Blur 0	Blur 2	Blur 4
7	0	-	0	1	1	0
8	2	1	1	2	-	1
9	-	0	2	1	1	1
10	0	1	1	-	1	1
11	1	3	-	1	1	1
12	1	2	1	1	3	-
Total	4	7	5	6	7	4

Rural

1:40,000	AM			SXS		
Subject No.	Blur 0	Blur 2	Blur 4	Blur 0	Blur 2	Blur 4
13	1	3	1	0	1	0
14	4	2	0	2	3	0
15	2	1	0	1	0	0
16	2	0	2	3	3	2
17	0	1	1	0	0	2
18	1	0	0	0	0	2
Total	10	7	4	6	7	6

EXPERIMENT II SUBJECT NUMBER WITH EACH PHOTO AND CONDITION NON-P.I.

Industrial

1:10,000		AM			SXS		
Picture No.	Changes	Blur 0	Blur 2	Blur 4	Blur 0	Blur 2	Blur 4
1	4	1	5	3	2	6	4
2	1	2	6	4	1	5	3
3	6	3	1	5	4	2	6
4	4	4	2	6	3	1	5
5	4	5	3	1	6	4	2
6	2	6	4	2	5	3	1

Suburban

1:10,000		AM			SXS		
Picture No.	Changes	Blur 0	Blur 2	Blur 4	Blur 0	Blur 2	Blur 4
9	1	1	5	3	2	6	4
10	1	2	6	4	1	5	3
11	2	3	1	5	4	2	6
12	3	4	2	6	3	1	5
13	1	5	3	1	6	4	2
14	1	6	4	2	5	3	1

Rural

1:10,000		AM			SXS		
Picture No.	Changes	Blur 0	Blur 2	Blur 4	Blur 0	Blur 2	Blur 4
17*	4	1	5	3	2	6	4
18	1	2	6	4	1	5	3
19	0	3	1	5	4	2	6
20	2	4	2	6	3	1	5
21	2	5	3	1	6	4	2
22	0	6	4	2	5	3	1

Industrial

1:40,000		AM			SXS		
Picture No.	Changes	Blur 0	Blur 2	Blur 4	Blur 0	Blur 2	Blur 4
1	6	13	17	15	14	18	16
2	4	15	13	17	16	14	18
3	6	17	15	13	18	16	14
4	3	14	18	16	13	17	15
5	5	16	14	18	15	13	17
6	5	18	16	14	17	15	13

Suburban

1:40,000		AM			SXS		
Picture No.	Changes	Blur 0	Blur 2	Blur 4	Blur 0	Blur 2	Blur 4
9	3	13	17	15	14	18	16
10	10	15	13	17	16	14	18
11	3	17	15	13	18	16	14
12	4	14	18	16	13	17	15
13	1	16	14	18	15	13	17
14	6	18	16	14	17	15	13

Rural

1:40,000		AM			SXS		
Picture No.	Changes	Blur 0	Blur 2	Blur 4	Blur 0	Blur 2	Blur 4
17	4	13	17	15	14	18	16
18	5	15	13	17	16	14	18
19	4	17	15	13	18	16	14
20	4	14	18	16	13	17	15
21	6	16	14	18	15	13	17
22	3	18	16	14	17	15	13

Industrial

1:20,000		AM			SXS		
Picture No.	Changes	Blur 0	Blur 2	Blur 4	Blur 0	Blur 2	Blur 4
1	2	7	11	9	8	12	10
2	5	9	7	11	10	8	12
3	8	11	9	7	12	10	8
4	1	8	12	10	7	11	9
5	5	10	8	12	9	7	11
6	4	12	10	8	11	9	7

Suburban

1:20,000		AM			SXS		
Picture No.	Changes	Blur 0	Blur 2	Blur 4	Blur 0	Blur 2	Blur 4
7	5	7	11	9	8	12	10
8	4	9	7	11	10	8	12
9	3	11	9	7	12	10	8
10	3	8	12	10	7	11	9
11	2	10	8	12	9	7	11
12	7	12	10	8	11	9	7

Rural

1:20,000		AM			SXS		
Picture No.	Changes	Blur 0	Blur 2	Blur 4	Blur 0	Blur 2	Blur 4
13	3	7	11	9	8	12	10
14	0	9	7	11	10	8	12
15	2	11	9	7	12	10	8
16	2	8	12	10	7	11	9
17	1	10	8	12	9	7	11
18	1	12	10	8	11	9	7

* Slides numbered 7, 8, 15, 16, 23, and 24 from P.I. stimulus set were not used for Non-P.I. Group.

PERCENT TARGETS DETECTED EXPERIMENT II P.I.

	1:10,000		AM		SXS	
	Picture No.	Total Changes	Blur 0	Blur 4	Blur 0	Blur 4
Industrial	1	4	25	0	50	25
	2	1	100	0	100	0
	3	6	100	50	83	83
	4	4	75	50	50	25
	5	4	50	25	50	25
	6	2	100	100	100	100
	7	4	25	25	25	50
	8	1	100	0	0	0
	Total	26	575	250	458	308

	1:40,000		AM		SXS	
	Picture No.	Total Changes	Blur 0	Blur 4	Blur 0	Blur 4
Industrial	1	6	83	33	50	50
	2	4	50	50	25	50
	3	6	33	33	17	17
	4	3	100	33	67	67
	5	5	60	20	60	60
	6	5	20	20	20	0
	7	2	100	100	50	50
	8	1	100	0	100	0
	Total	32	546	289	389	294

	1:10,000		AM		SXS	
	Picture No.	Total Changes	Blur 0	Blur 4	Blur 0	Blur 4
Suburban	9	1	0	0	100	0
	10	1	0	0	0	0
	11	2	50	100	50	100
	12	3	67	67	33	67
	13	1	100	0	100	0
	14	1	100	0	100	0
	15	7	86	71	29	57
	16	3	100	33	100	33
	Total	19	503	271	512	257

	1:40,000		AM		SXS	
	Picture No.	Total Changes	Blur 0	Blur 4	Blur 0	Blur 4
Suburban	9	3	0	33	0	0
	10	10	30	30	50	10
	11	3	67	67	100	33
	12	4	75	75	25	0
	13	1	0	100	0	0
	14	6	83	50	17	33
	15	5	60	60	60	40
	16	2	100	0	50	0
	Total	34	415	415	302	116

	1:10,000		AM		SXS	
	Picture No.	Total Changes	Blur 0	Blur 4	Blur 0	Blur 4
Rural	17	4	50	0	75	25
	18	1	0	0	0	0
	19	None	100	100	100	100
	20	2	50	0	50	50
	21	2	100	0	100	0
	22	None	100	100	100	100
	23	3	100	67	33	33
	24	3	67	33	33	0
	Total	15	567	300	491	308

	1:40,000		AM		SXS	
	Picture No.	Total Changes	Blur 0	Blur 4	Blur 0	Blur 4
Rural	17	4	75	25	50	50
	18	5	100	20	40	60
	19	4	25	50	25	0
	20	4	50	0	0	0
	21	6	67	50	50	33
	22	3	33	67	67	33
	23	5	60	20	60	20
	24	5	60	0	100	20
	Total	36	470	232	392	216

NUMBER OF TARGETS DETECTED P.I. EXPERIMENT II

	1:10,000		AM		SXS	
	Picture No.	Changes	Blur 0	Blur 4	Blur 0	Blur 4
Industrial	1	4	1	0	2	1
	2	1	1	0	1	0
	3	6	6	3	5	5
	4	4	3	2	2	1
	5	4	2	1	2	1
	6	2	2	2	2	2
	7	4	1	1	1	2
	8	1	1	0	0	0
	Total	26	17	9	15	12

	1:40,000		AM		SXS	
	Picture No.	Changes	Blur 0	Blur 4	Blur 0	Blur 4
Industrial	1	6	5	2	3	3
	2	4	2	2	1	2
	3	6	2	2	1	1
	4	3	3	1	2	2
	5	5	3	1	3	3
	6	5	1	1	1	0
	7	2	2	2	1	1
	8	1	1	0	1	0
	Total	32	19	11	13	12

	1:10,000		AM		SXS	
	Picture No.	Changes	Blur 0	Blur 4	Blur 0	Blur 4
Suburban	9	1	0	0	1	0
	10	1	0	0	0	0
	11	2	1	2	1	2
	12	3	2	2	1	2
	13	1	1	0	1	0
	14	1	1	0	1	0
	15	7	6	5	2	4
	16	3	3	1	3	1
	Total	19	14	10	10	9

	1:40,000		AM		SXS	
	Picture No.	Changes	Blur 0	Blur 4	Blur 0	Blur 4
Suburban	9	3	0	1	0	0
	10	10	3	3	5	1
	11	3	2	2	3	1
	12	4	3	3	1	0
	13	1	0	1	0	0
	14	6	5	3	1	2
	15	5	3	3	3	2
	16	2	2	0	1	0
	Total	34	18	16	14	6

	1:10,000		AM		SXS	
	Picture No.	Changes	Blur 0	Blur 4	Blur 0	Blur 4
Rural	17	4	2	0	3	1
	18	1	0	0	0	0
	19	0	-	-	-	-
	20	2	1	0	1	1
	21	2	2	0	2	0
	22	0	-	-	-	-
	23	3	3	2	1	1
	24	3	2	1	1	0
	Total	15	10	3	8	3

	1:40,000		AM		SXS	
	Picture No.	Changes	Blur 0	Blur 4	Blur 0	Blur 4
Rural	17	4	3	1	2	2
	18	5	5	1	2	3
	19	4	1	2	1	0
	20	4	2	0	0	0
	21	6	4	3	3	2
	22	3	1	2	2	1
	23	5	3	1	3	1
	24	5	3	0	5	1
	Total	36	22	10	18	10

TOTAL TIMES (SECONDS) SPENT ON PICTURES EXPERIMENT II P.I.

	1:10,000	AM		SXS	
	Picture No.	Blur 0	Blur 4	Blur 0	Blur 4
Industrial	1	188	224	143	137
	2	96	101	200	208
	3	214	115	173	125
	4	32	80	127	171
	5	158	90	189	124
	6	74	157	71	74
	7	74	67	125	148
	8	171	90	165	128
	Total	1007	924	1193	1115

	1:40,000	AM		SXS	
	Picture No.	Blur 0	Blur 4	Blur 0	Blur 4
Industrial	1	266	181	172	111
	2	195	146	123	345
	3	178	217	106	174
	4	120	80	210	189
	5	67	117	90	178
	6	106	151	325	148
	7	143	126	190	401
	8	104	121	44	112
	Total	1179	1139	1260	1658

	1:10,000	AM		SXS	
	Picture No.	Blur 0	Blur 4	Blur 0	Blur 4
Suburban	9	195	152	86	106
	10	115	86	208	252
	11	82	134	77	85
	12	47	34	178	148
	13	87	180	119	110
	14	162	40	78	70
	15	142	91	184	209
	16	145	134	94	66
	Total	975	851	1024	1046

	1:40,000	AM		SXS	
	Picture No.	Blur 0	Blur 4	Blur 0	Blur 4
Suburban	9	166	146	107	83
	10	109	120	241	241
	11	199	371	184	334
	12	184	127	330	232
	13	218	126	252	160
	14	220	296	391	282
	15	145	122	298	214
	16	118	80	111	64
	Total	1359	1388	1914	1610

	1:10,000	AM		SXS	
	Picture No.	Blur 0	Blur 4	Blur 0	Blur 4
Rural	17	262	94	145	192
	18	60	68	120	141
	19	98	142	60	94
	20	49	102	134	69
	21	66	40	127	85
	22	120	97	100	136
	23	42	102	89	194
	24	43	229	112	60
	Total	740	874	887	971

	1:40,000	AM		SXS	
	Picture No.	Blur 0	Blur 4	Blur 0	Blur 4
Rural	17	161	134	224	129
	18	155	139	160	72
	19	65	130	108	123
	20	112	72	175	258
	21	100	103	185	147
	22	93	92	240	136
	23	131	86	160	184
	24	182	100	128	212
	Total	999	856	1380	1261

COMMISSION ERRORS EXPERIMENT II P.I.

	1:10,000	AM		SXS	
	Picture No.	Blur 0	Blur 4	Blur 0	Blur 4
Industrial	1	0	2	1	2
	2	1	3	1	2
	3	0	0	0	1
	4	0	0	0	0
	5	2	0	0	0
	6	1	2	3	1
	7	2	0	0	1
	8	0	0	3	0
	Total	6	7	8	7

	1:40,000	AM		SXS	
	Picture No.	Blur 0	Blur 4	Blur 0	Blur 4
Industrial	1	1	1	0	1
	2	3	4	2	7
	3	0	1	1	1
	4	0	2	1	0
	5	1	2	5	2
	6	1	0	0	1
	7	0	2	0	0
	8	0	0	0	1
	Total	6	12	9	13

	1:10,000	AM		SXS	
	Picture No.	Blur 0	Blur 4	Blur 0	Blur 4
Suburban	9	2	3	1	0
	10	0	1	1	2
	11	0	0	0	0
	12	0	0	0	1
	13	1	2	0	0
	14	1	0	1	1
	15	0	0	2	0
	16	1	0	0	0
	Total	5	6	5	4

	1:40,000	AM		SXS	
	Picture No.	Blur 0	Blur 4	Blur 0	Blur 4
Suburban	9	3	1	1	1
	10	3	3	2	1
	11	0	4	4	8
	12	1	0	2	1
	13	2	0	2	2
	14	1	2	3	1
	15	2	1	2	1
	16	0	0	2	0
	Total	12	11	18	15

	1:10,000	AM		SXS	
	Picture No.	Blur 0	Blur 4	Blur 0	Blur 4
Rural	17	1	0	2	3
	18	0	2	0	1
	19	1	4	0	4
	20	2	2	1	0
	21	0	0	0	0
	22	0	1	0	1
	23	1	0	3	0
	24	1	0	0	0
	Total	6	9	6	9

	1:40,000	AM		SXS	
	Picture No.	Blur 0	Blur 4	Blur 0	Blur 4
Rural	17	3	0	5	3
	18	0	0	1	0
	19	0	1	1	1
	20	0	1	1	4
	21	0	0	0	0
	22	0	0	1	0
	23	3	1	0	1
	24	0	0	1	0
	Total	6	3	10	9

NUMBER OF TARGETS DETECTED BY SUBJECT NUMBER
EXPERIMENT II P.I.

	1:10,000	AM		SXS	
	Subject Number	Blur 0	Blur 4	Blur 0	Blur 4
Industrial	1	1	3	2	0
	2	2	0	2	5
	3	3	1	0	2
	4	1	2	2	2
	5	6	0	1	1
	6	1	1	5	1
	7	1	2	2	0
	8	2	0	1	1
	Total	17	9	15	12

	1:40,000	AM		SXS	
	Subject Number	Blur 0	Blur 4	Blur 0	Blur 4
Industrial	1	2	2	1	2
	2	1	1	1	3
	3	2	2	1	3
	4	1	1	1	1
	5	5	2	2	0
	6	3	1	3	1
	7	2	2	3	0
	8	3	0	1	2
	Total	19	11	13	12

	1:10,000	AM		SXS	
	Subject Number	Blur 0	Blur 4	Blur 0	Blur 4
Suburban	1	0	2	1	0
	2	1	0	1	2
	3	6	2	1	1
	4	1	1	2	2
	5	1	0	0	0
	6	0	0	1	0
	7	2	5	3	0
	8	3	0	1	4
	Total	14	10	10	9

	1:40,000	AM		SXS	
	Subject Number	Blur 0	Blur 4	Blur 0	Blur 4
Suburban	1	2	1	1	0
	2	5	3	3	0
	3	3	3	0	0
	4	0	0	3	1
	5	0	2	1	2
	6	3	3	0	1
	7	3	3	1	0
	8	2	1	5	2
	Total	18	16	14	6

	1:10,000	AM		SXS	
	Subject Number	Blur 0	Blur 4	Blur 0	Blur 4
Rural	1	2	-	2	0
	2	2	0	3	-
	3	1	2	-	0
	4	-	1	1	1
	5	-	0	0	0
	6	0	0	-	1
	7	3	0	1	-
	8	2	-	1	1
	Total	10	3	8	3

	1:40,000	AM		SXS	
	Subject Number	Blur 0	Blur 4	Blur 0	Blur 4
Rural	1	1	1	2	0
	2	1	0	1	2
	3	4	1	5	3
	4	3	1	3	1
	5	3	2	0	1
	6	2	2	2	0
	7	3	3	2	1
	8	5	0	3	2
	Total	22	10	18	10

SUBJECT NUMBER WITH EACH PHOTO CONDITION

EXPERIMENT II P.I.

	1:10,000	AM		SXS	
	Picture No.	Blur 0	Blur 4	Blur 0	Blur 4
Industrial	1	1	5	2	6
	2	6	2	5	1
	3	5	1	6	2
	4	3	7	4	8
	5	2	6	1	5
	6	8	4	7	3
	7	7	3	8	4
	8	4	8	3	7

	1:40,000	AM		SXS	
	Picture No.	Blur 0	Blur 4	Blur 0	Blur 4
Industrial	1	5	1	6	2
	2	3	7	4	8
	3	1	5	2	6
	4	6	2	5	1
	5	8	4	7	3
	6	2	6	1	5
	7	7	3	8	4
	8	4	8	3	7

	1:10,000	AM		SXS	
	Picture No.	Blur 0	Blur 4	Blur 0	Blur 4
Suburban	9	1	5	2	6
	10	6	2	5	1
	11	5	1	6	2
	12	7	3	8	4
	13	2	6	1	5
	14	4	8	3	7
	15	3	7	4	8
	16	8	4	7	3

	1:40,000	AM		SXS	
	Picture No.	Blur 0	Blur 4	Blur 0	Blur 4
Suburban	9	5	1	6	2
	10	7	3	8	4
	11	1	5	2	6
	12	6	2	5	1
	13	4	8	3	7
	14	2	6	1	5
	15	3	7	4	8
	16	8	4	7	3

	1:10,000	AM		SXS	
	Picture No.	Blur 0	Blur 4	Blur 0	Blur 4
Rural	17	1	5	2	6
	18	6	2	5	1
	19	5	1	6	2
	20	3	7	4	8
	21	2	6	1	5
	22	4	8	3	7
	23	7	3	8	4
	24	8	4	7	3

	1:40,000	AM		SXS	
	Picture No.	Blur 0	Blur 4	Blur 0	Blur 4
Rural	17	5	1	6	2
	18	8	4	7	3
	19	1	5	2	6
	20	6	2	5	1
	21	3	7	4	8
	22	2	6	1	5
	23	7	3	8	4
	24	4	8	3	7

APPENDIX VII

EXPERIMENT III RAW DATA

EXPERIMENT III RAW DATA P.I. AND NON-P.I.

CORRECT DETECTIONS

Subject Number	P.I.						NON-P.I.					
	AM			SXS			AM			SXS		
	5 Month	10 Month	15 Month	5 Month	10 Month	15 Month	5 Month	10 Month	15 Month	5 Month	10 Month	15 Month
1	1	4	2	2	4	1	1	7	2	4	6	2
2	5	5	0	0	2	1	2	6	0	1	3	2
3	4	4	1	5	0	4	5	5	4	6	7	7
4	4	2	5	4	3	3	5	1	5	5	3	4
5	2	1	5	2	2	3	2	2	5	4	2	4
6	3	2	3	6	3	5	1	1	0	1	0	3
7	5	3	3	4	3	5	3	2	3	4	1	5
8	2	3	4	3	0	3	1	3	3	5	0	3
9	2	3	0	4	2	2	4	1	0	2	3	1
10	4	2	2	3	2	2	4	3	2	6	4	3
11	4	7	5	3	6	1	1	3	0	1	2	1
12	1	2	2	2	2	3	3	4	3	2	4	3
*Total	37	38	32	38	29	33	32	38	27	41	35	38

COMMISSION ERRORS

Subject Number	P.I.						NON-P.I.					
	AM			SXS			AM			SXS		
	5 Month	10 Month	15 Month	5 Month	10 Month	15 Month	5 Month	10 Month	15 Month	5 Month	10 Month	15 Month
1	1	0	0	0	1	0	0	1	0	0	0	1
2	0	0	0	1	0	1	0	0	0	0	0	0
3	0	0	1	0	0	0	0	0	1	0	1	1
4	0	2	0	1	0	1	0	0	0	1	0	0
5	0	0	0	1	2	1	1	0	0	0	1	1
6	1	0	0	0	0	0	1	0	1	0	0	1
7	0	1	1	1	2	1	1	2	1	0	2	1
8	0	0	0	0	0	0	0	0	0	1	0	0
9	3	1	6	2	0	1	0	1	0	0	0	1
10	1	2	1	2	1	5	0	0	0	0	0	0
11	0	0	1	1	0	2	0	0	1	0	0	1
12	2	1	0	0	3	0	1	0	2	1	0	3
Total	8	7	10	9	9	12	4	4	6	3	4	10

TOTAL TIME (MINUTES)

Subject Number	P.I.						NON-P.I.					
	AM			SXS			AM			SXS		
	5 Month	10 Month	15 Month	5 Month	10 Month	15 Month	5 Month	10 Month	15 Month	5 Month	10 Month	15 Month
1	2.2	3.1	3.7	3.7	3.8	5.0	3.1	4.2	3.4	3.2	6.2	4.5
2	2.8	2.6	2.8	2.4	2.5	2.9	2.0	2.5	1.5	1.8	2.9	2.5
3	2.8	4.4	2.5	3.3	3.7	2.7	3.1	2.9	3.8	3.4	4.6	3.1
4	3.1	3.4	3.0	3.8	4.9	4.1	2.3	4.8	4.0	5.0	5.6	4.5
5	4.5	2.4	3.1	3.6	3.4	2.7	5.5	3.8	3.3	6.6	3.8	4.7
6	3.7	1.8	2.7	2.9	3.3	3.7	1.5	1.5	1.8	2.2	1.7	2.5
7	6.6	8.2	6.8	7.6	4.8	6.4	3.1	5.2	3.3	4.1	3.1	3.8
8	2.1	2.4	2.2	1.3	2.7	2.4	2.3	3.6	3.8	4.2	2.2	3.5
9	1.7	1.6	2.7	2.0	1.3	1.3	2.5	1.9	1.8	3.0	2.0	1.7
10	3.3	2.9	3.4	2.1	2.4	3.9	2.4	2.9	2.4	3.3	3.5	4.8
11	4.1	4.1	3.9	2.6	4.1	3.0	3.4	3.1	2.9	2.6	3.6	2.5
12	2.4	3.0	1.6	4.0	3.8	2.5	2.0	1.5	2.2	1.7	1.2	2.5
**Total	39.3	39.9	38.4	39.3	40.7	40.6	33.2	37.9	34.2	41.1	40.4	40.6

* Note: Total possible = 8 per subject per condition

** Note: 2 photos per subject per condition